Introduction

In reporting upon Programmed Instruction (referred to subsequently as P.I.), we make no claim to represent 'official' views from any particular Service Department or establishment. We have tried to take account of all documentary evidence available to us about Service work in P.I. Nevertheless, what follows is drawn principally from our own collective experience, and from our general acquaintance with relevant research elsewhere. We have been sparing with references throughout the text, but have included a short bibliography at the end of Appendix 1.

As applied psychologists, we are disposed to interpret "research into Service training" as "research into the techniques of training by which Service objectives are realised". Our present report is concerned with P.I. as one of these techniques of training. Quite early in our discussions, however, we found ourselves severely handicapped by the absence of any agreed taxonomy of Service tasks or skills. Nor had we any ready-made classification of human skills which could immediately be applied in this context.

In an attempt to overcome this lack we have evolved a provisional two-way classification of Training Areas and Instructional Methods. As we hope to continue using this model as a guide to our future enquiries, a copy of it has been included at page 47. The classification lists different categories of military training areas in the left-hand margin, and instructional methods along the top margin. The training areas form a comprehensive list of the major fields of military training which can be distinguished on an empirical basis. (The list does not yet form a taxonomy of actual training tasks, although the development of such a taxonomy is most desirable.) Instructional methods have been divided into three groups, based on student-centred, instructor-centred, and equipment-centred methods. We have not shown completed entries in the various 'cells' of the classification; though we envisage using them to indicate which instructional methods are in fact, or potentially, in use for different training areas.

Programmed instruction is regarded as a subdivision of student-centred methods of instruction. The relevance of P.I. for each of the military training areas listed is discussed later. The use of the other training methods will be discussed in later reports; and it should eventually be possible to complete the cells of the classification table to show which training methods may be appropriate for any military training area.

The Meaning of Programmed Instruction

The term is used here to connote a general approach to teaching and training which is also identified with such labels as Programmed Learning, Teaching Machines, Self-Instruction, and Automated Instruction. These last three terms are not, however, synonymous with each other or with P.I. It is by no means necessary to present programmes by automatic or even mechanised devices; nor are all forms of self-instruction programmed, in the sense defined below.

Instruction, or training, is 'programmed' when the subject-matter or content of the course displays the following defining characteristics:

(a) There is a clear-cut statement of objectives, i.e. of 'terminal performance'.

(b) The material to be learned has been itemised and is presented serially in identifiable steps, i.e. frames.

(c) The actual sequence of frames which any student encounters is controlled according to rules derived from the particular programming technique employed.

(d) Frequent and unambiguous responses from every student are required throughout the whole sequence.

(e) Feedback of information about the correctness or otherwise of responses is given to the student before the next frame is presented.

(f) A 'response comparator' is implicit in (e) above to judge between actual and desired (i.e. 'correct') responses. This function can be performed by the student or by a device.

These are minimal requirements only. Nevertheless they are rigorous enough to allow the unequivocal classification of any educational or training course as being an example of P.I. or not. It may also be pointed out that, in principle, P.I. should be applicable to any training objective which can be specified.

Many other characteristics have, however, been claimed at one time or another as vital to the concept of a programme. Some of these we acknowledge to be highly desirable, but not among the defining characteristics. The specification of objectives in *behavioural* terms* is probably a prerequisite of the best programmes, but may not be entirely practicable on every occasion. A full-scale internal and external *evaluation*, following approved procedures, is another example.

There are several more features concerning which it is now quite clear that considerable variation is not only permissible, but necessary; contrary though this is to earlier, 'classical', expressions of programming requirements. Among these features we may single out:

(a) The theory of learning from which the type of sequencing is deduced. For example, this may prescribe the same sequence for all students (linear); or a sequence which varies for different students according to their differential responses to an immediately-preceding frame (intrinsic branching); or it may call for completely flexible sequencing, dependent upon an accumulated history of past responses (adaptive).

(b) The device by means of which a programme is presented, and through which the actual control of sequences is effected. This may be automatic, mechanical, or entirely non-mechanical, in operation. Its displays may be visual or aural; or even tactual and kinaesthetic if training objectives imply the need.

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* E.g. "After training, the student will be able to measure electrical resistance, voltage, current, and valve characteristics, within the (specified) following classes of electronic equipment, using the (specified) following measuring instruments . . . ." *rather than* "A trained man must be able to use test equipments efficiently, as a basis for carrying out standard maintenance-schedule routines".

(c) The extent to which a student's rate of progress through a programme is under his own control. In the early days of P.I. it became almost an 'article of faith' that self-pacing was an indispensable feature. The evidence for this has never been extensive nor particularly convincing; and nowadays the insistence on unrestricted self-pacing is slackening. Whilst the customary 'lock-step' pacing of a conventional classroom group is just as much to be deprecated as ever, the possibility is beginning to be recognised that some forms of group-controlled pacing, and 'adaptive' pacing for individuals, are potentially advantageous.

(d) Response mode, step (and frame) size: these aspects of P.I. were at one time the centres of lively controversy. It now seems unwarranted to take up a dogmatic position with respect to either of these issues. Decisions about whether or not to use constructed, discriminatory, or multiple-choice, responses cannot yet be made on theoretical grounds; they should be influenced by the total situation in which a programme is being prepared, and particularly by the nature of the terminal behaviour to be acquired. Similar attention to all the circumstances should precede decisions about how much information appears on a frame, and what increments are acceptable between frames. And in either case, decisions should be open to revision in the light of evaluative data.

A Summary of P.I. Studies in the Services

The Service departments have been pioneers in the United Kingdom with respect both to programme writing and to studies of presentation devices and productive ways of using P.I. Most of this work is documented; some of it has been published in the appropriate journals. However, we regarded it as desirable to bring together as much of the reported data as seemed relevant to our present brief. Since some readers may be familiar with some of this work, we have included the summary as Appendix 1.

Trends in P.I. Research and Development

In this section we wish to draw attention to certain trends which are sufficiently pronounced for there to be no doubt of their relevance to Service progress in utilising P.I. Not surprisingly, the United States is where the trends emerge most clearly. However, what follows is also represented strongly in current interest and discussion in the United Kingdom, though it is not necessarily indicative of where most effort is now being expended.

The Concept of a Technology of Training

Refinement of technique in programme writing and evaluation has been more conspicuous than concern with the economics and administration of P.I. Nevertheless, attention has been directed increasingly to some of the concomitant factors which condition the effectiveness of P.I. In those cases where the whole field of design and practical operation of a training course has been studied (. . . not only programmed, but 'conventional' courses too), the *efficiency* of training has clearly been shown to depend on many factors. The quality of instruction is only one of these factors. The relevance and reliability of proficiency measures, during and after training, is another.

Some of these factors can be identified as stages in the actual development of a well-designed training course. One expression of these succeeding stages might be:

(a) task and behavioural analysis of the job to be learned,

(b) declaration of training objectives, in behavioural terms, and construction of a criterion test of acceptable performance,

(c) determination of the knowledge and abilities available within the population of potential trainees,

(d) specification of the training course, including prescription of content and practice of instructional methods such as P.I.,

(e) assessment of training effectiveness, using objective proficiency measures and cost criteria.

There is a wide measure of acknowledgment in the United States that maximal efficiency in training is unattainable unless all these stages have been undertaken. What many psychologists refer to as a 'technology of training' consists of the various techniques and professional methods which have been developed to accommodate these stages in the design and construction of a training course. Not all of these techniques are new, nor are they all highly developed. Perhaps the most critical in terms of ultimate success in writing programmes (or preparing *any* method of instruction) are those which lead to the declaration of training objectives in behavioural terms, i.e. to 'terminal behaviour'. The terms 'behavioural analysis' and 'task analysis' are commonly used of the various procedures which are used to define terminal behaviour. By 'task analysis' is meant a rigorous psychological analysis of what has to be learned, taking as the starting point an objective study of the knowledge and skill required in the operational situation itself. 'Behavioural analysis' is sometimes used to cover not only the breakdown in behavioural terms of the tasks to be learned, but also of the intermediate stages of knowledge and performance through which a trainee must pass in order to attain the terminal behaviour itself.

The concept of a training technology is particularly relevant to our present topic, since the factors summarised above can almost be regarded as a paradigm for P.I. itself. It is indeed largely due to the academic and practical interest aroused by P.I. that the notion of a general technology of training, with its much wider implications, is beginning to take root. As this happens, we may expect to hear less expression of the misguided view that P.I. offers a straightforward solution to all our training problems; or, conversely, that it threatens the professional teacher and trainer with a form of automation at its worst. A glance at page 47 should leave no doubt that there are many other components of training than P.I., at least as we know it today.

Extensions of P.I. to Various Training Areas

During the first decade of P.I., programmes have generally been confined within two training areas which we have labelled *acquisition of information* and *intellectual skills* (see page 47). Academic and commercial interests have together predisposed programmers to concentrate upon educational subject-matters, 'background' factual information relevant to particular vocational fields, and intellectual skills such as mathematics and electronic fault-finding. Most of the U.K. Service applications so far have also been directed towards academic, theoretical, and informational, aspects of technical training.

There are obvious reasons why the P.I. techniques as developed at present should continue to be applied principally in these fields. If there is one undisputed finding from our experience to date, it is that the effort and time required to prepare a good programme is so great as to deter its being expended (at least within the Services) on training objectives which are liable to radical and frequent change. Likewise it is most profitable to direct programming effort towards courses with a large and steady through-put of students, where there is promise of reducing overheads in terms of failure-rates, training-time, and instructional staff.

The potential for P.I. which remains in these two training areas is so great within each Service as to exhaust more than all the programming effort which can reasonably be anticipated. We are not in a position to judge just how far it is practicable to agree upon treatments of subject-matters which are ostensibly common to all three Services. However, we are convinced that serious attempts should be made to co-ordinate the programming work which each Service undertakes in the aforementioned aspects of basic and advanced technical and educational instruction.

Without wishing to retract our statement that P.I. is by no means a panacea for all training problems, we nevertheless regard it as important that the Services should not fail to take advantage of other developments in P.I. technique, outside the two training areas just mentioned. As we have pointed out in the Appendix 1 (para. 28), the basic principles behind P.I. are not exclusive to the learning of verbal knowledge and intellectual skills. They are valid for manual and perceptual tasks, too; perhaps for some non-cognitive objectives also. However, the majority of skills listed on page 47 are highly specific in content. Certainly this is so of most procedural, perceptual, and control, operations; and it is probably characteristic of many managerial skills and group activities. If only for this reason, applications of P.I. within these categories are subject to more stringent demands of task and behavioural analysis. Moreover, the programmed courses, and presentation devices (which are likely to entail close simulation), are unlikely to be generalisable over a wide area of common Service use. It was probably a failure to take account at least of the former limitation that led to disappointing results from early American ventures in the programming of perceptual skills.

Nevertheless the majority of Service training is actually (or should be) concerned with the specific and practical aspects of operational activities, over and above the underlying theoretical and informational aspects. It is therefore incumbent upon us to investigate the extent to which the demonstrable benefits of P.I. can be extended to these other aspects. Hopes of realising this possibility are a potent factor in the recent upsurge of industrial interest in programming. So also have the Services begun to take action in this direction. Two recent examples may be cited.

The first is referred to in Appendix 1 (para. 15). It was soon realised in HMS COLLINGWOOD that the maximum benefit from their electronic maintenance courses could not be extracted whilst P.I. was restricted only to the 'theoretical' content, whilst practical and laboratory work was continued under conventional procedures. Rates of progress throughout a technical course remain contingent, under these circumstances, upon the organisation of group laboratory sessions; supervisory overheads are also higher than may be possible if the entire technical training is programmed. Though it is early yet to pronounce on the matter, there seems every likelihood (judging from experience in HMS COLLINGWOOD) that significant improvements will follow, in productivity as well as in the attainment of technical skill, from the programming of laboratory experiments and of instruction in the use of test instruments.

A second innovation is also noted in the Appendix (paras. 28 to 31). It is a project which has the object of developing distinctive P.I. courses for perceptual tasks such as occur in the classification of underwater targets. A feature of this adaptation is that P.I. techniques of cueing, feedback, and sequencing have to be associated with an appropriate simulation of critical task and equipment characteristics. This means that fairly sophisticated teaching machines, perhaps with auditory as well as visual displays, are likely to be indispensable. We should expect this requirement for relatively complex instrumentation to be characteristic of successful P.I. for control skills as well as for perceptual ones.

Another training area in which successful application has been demonstrated is that of *procedural skills*. An early and notable American example of programming a routine sequential task, where the elements are discrete, is afforded by the Hughes Aircraft Company's electronic assembly line. Here the operatives' work is directed by means of individual Videosonic teaching machines*. In many situations like this, it may not be necessary to *learn* the sequence, provided the elements themselves can be performed precisely and carried out under directions. This may be true of some standard maintenance schedules, switching-on drills, clerical routines, stores inspections, and many other Service procedures. In any event, whatever the extent to which the sequences, as well as individual elements, have to be learned and remembered, all these tasks lend themselves very well indeed to more effective and economic accomplishment through the medium of programmed materials. Nor is it necessary to envisage expensive or complicated teaching machines to accommodate the majority of such programmes.

We have already noted the extension of P.I., at present still under development, to *perceptual skills* in the sonar operating field. Training for perceptual tasks covers a wide range of objectives, from aircraft recognition and photographic interpretation, to visual and aural search and classification in a multiplicity of surveillance, weapons, and communication, systems. The basic ideas of P.I. and the specific cueing techniques which have become associated with discrimination training generally, are directly relevant to the instructional problems of these critical operating skills; and we should advocate that every opportunity should be taken when perceptual training equipments are being developed, to incorporate these improvements.

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* A recent British product, which appears to be similar in principle, is the Smith's Audio Diagnostic Instructional Equipment (SADIE), proposed for use in troop transport aircraft as an aid to maintainers. We are not in a position to judge whether or not this device successfully embodies all the requirements of a procedural P.I. system.

The training area which we have called *control skills* is also a very wide one. Within it we have distinguished *craft*, *operating* and *coding* skills. The first of these is an industrial commitment, too; and the recent urge to improve industrial training facilities for apprentices has produced the first attempts to apply P.I. for this purpose. The informational aspects of craft training (including workshop technology data) are naturally amenable to instruction by programmed, self-instructional, methods. It also seems, from the pilot demonstrations produced by a firm called Learning Systems Ltd., that machine-tool (as well as hand-tool) operations can be taught with the aid of programmed texts or teaching machines. Since one of the aims of this new application is to ease the supervisory load during workshop training, we hope the Services, for whom the teaching of craft skills represents so large an investment, will themselves take part in investigating and developing it. An exploratory study in this field has in fact already been started in association with the Navy's apprentice training establishment.

Operating and coding skills, which are exemplified respectively by continuous tracking tasks and by keyboard tasks are not likely to offer scope for the simpler techniques of P.I. Both these areas, however, continue to be the subject of research designed to produce appropriate 'adaptive' programming devices for training. (Adaptive P.I. is introduced in the following section.) The Army has already sponsored a university research into adaptive training of 2-dimensional tracking. One of the difficulties here lies in the prior task analysis; the structure of a skill must be specified before the design of a suitable 'adaptive' trainer can proceed. It is not yet determined whether there is enough common ground among tracking, or keyboard, skills to make it worthwhile to employ 'generalised' trainers for the personnel who must master various individual tasks. In any event, one of the characteristics of an adequate instructional system for any of these skills is almost certain to be an 'adaptive' capability.

Most of the effort in industrial as well as military training, so far as P.I. is concerned, will continue to be taken up in the five training areas we have so far surveyed. Among the remaining six areas in the list on page 47, a serious interest in P.I. has so far only been evident with respect to *managerial skills*. This is principally due to industrial prompting. However, the Services have been equally involved in management training and will presumably expand even further in carrying out this function as the load of technical expertise increases. So far as we are aware, the only commercial programme on management which has been used in a Service context, in the Army, is the U.S. Industries "Effective Executive Practices"; this programme seems to have demonstrated some usefulness in an industrial context. However, we cannot from present evidence hazard more than a guess that P.I. could make a worthwhile contribution to Service management training. Programmes on the 'tools' of personnel and technical management (examples could be PERT and MILITARY LAW) would no doubt be relevant and helpful. Whether a contribution based on P.I. could extend beyond the informational basis of leadership, decision-making, or staff activity, is a matter for conjecture until some preliminary research has been carried out into the nature of the requirements.

The situation appears to us substantially the same with respect to the remaining five training areas, i.e. *physical fitness, character-building, identification with the group, system activities*, and *operational formations*. Non-cognitive components are dominant among three of these, and they are also critical to system activities. Surprisingly, perhaps, the attainment of physical fitness may well be the area in which programming principles would most probably repay application. One of the newest avenues to athletic skill ('circuit training'), though constructed in complete independence of P.I. influences, in fact incorporates several key features of a programmed course. It may well be that its success is attributable to these (knowledge of performance, regular experience of success, and an 'itemised' sequence of activities); and that further improvements are possible from a more deliberate integration of the two approaches.

System activities are clearly built on foundations of individual skills, which are themselves likely to be amenable to P.I. but the distinctively 'group' aspects of system activity present training problems for which accustomed forms of P.I. will probably not be very helpful. At present, although there have been no Service investigations of the medium, it seems that 'adaptive' group teaching machines (see the following section) offer the most likely outlet for applying P.I. techniques.

There is so little which we can say with any confidence about the other areas, with respect to P.I., that we think it wise to reserve further comment. What does seem to us to be notably lacking in these areas is a reliable corpus of systematic research information, based upon U.K. experience, from which to begin an assessment of whether or not P.I. has any distinctive contribution to offer.

'Adaptive' and Computer-based Instructional Systems

What we have discussed represents a selective view of current ideas and developing practice within the 'orthodox', or generally-accepted, framework of P.I. (By 'orthodox', we mean no more than that the principles are based upon one or another paradigm which is conspicuous in psychological learning theory, and that the instructional sequences followed are either pre-determined completely or are subject to variation within narrow limits set by an immediately-preceding response only.)

Very early in the 'history' of P.I., however, the cybernetic view of a learning system, in which the accumulated record of past responses is at all times influential in guiding future states of the system, began to attract notice. The pioneer in this respect has been Gordon Pask, of System Research Ltd., in the United Kingdom. Programmes had to be 'adaptive', i.e. flexible in the sequencing they permitted, if they were to meet the criteria of a cybernetic model. In this section, therefore, we shall comment on some relevant features of this approach to P.I., which also affords a logical introduction to the ideas which lie behind computer-aided instructional systems.

'Adaptive' Teaching Machines. Devices which are 'adaptive' in the sense used by Gordon Pask and his associates may be briefly characterised as follows:

(a) The difficulty level of the lesson is continually adjusted to suit a wide range of individual ability — i.e. to maximise the rate of improvement. Typically, cues are introduced or withdrawn, and the pace is varied.

(b) In order to achieve (a), responses must be classified into types and information about each type separately stored. The interpretation of this information determines the course of the lesson for a particular individual, i.e. the device bases the lesson on what it can learn about its pupil.

(c) Interpretation of response information may consist of built-in decision rules or, it is claimed, the device itself may select and modify decision rules on the basis of their past effectiveness, i.e. it may base the lessons on what it has learned about a population of pupils.

Apart from the superior capacity to cope with individual differences, which is implicit in the foregoing characteristics, adaptive teaching machines are said to have a superior motivational property. Pask speaks of "maintaining the requisite variety". Lewis is more explicitly psychological: "Now it so happens that humans have an irresistible tendency to withdraw (through boredom) from tasks that are too easy and to withdraw (through frustration) from tasks that are too difficult, . . . machines must therefore determine . . . a level of difficulty which the student regards as being neither too easy nor too difficult". (Lewis, 1963a.)

This position on motivation is a very plausible one, but it should be recognised as a credo. One might argue that the appeal of "a level of difficulty which the student regards as being neither too easy nor too difficult" may lie in a tendency of current training methods to *deprive* the trainee of this state of affairs; and that a motivational effect produced by deprivation may be subject to satiation. (It has been argued that a high level of correct responses in a Skinnerian programme is therefore only apparently and temporarily reinforcing.) The point to note here is that *a priori* arguments about motivation are best distrusted until shown to be demonstrably true in extended empirical studies.

It has nevertheless been claimed that devices exhibiting adaptive characteristics have been realised for the following skills:

(a)	*Keyboard Skills*:	SAKI is the well-known example.
(b)	*Radar Detection*:	of a wide range of faint signals, presented at irregular intervals, against varying noise backgrounds.
(c)	*Radar Tracking*:	of targets of varying 'elusiveness'.
(d)	*Fault Finding*:	i.e. correction of incorrect diagnoses and search strategies.
(e)	*'General Comprehension'*	of verbal material, by means of multiple-choice questions.

However, whilst these devices have been constructed and do, in fact, exhibit 'adaptive' characteristics, evaluation studies establishing their effectiveness or efficiency are lacking. The middle three, particularly, are not very promising for Service purposes, since they are based upon assumptions about the underlying generality of perceptual and control skills which do not stand up to the test of practical experience.

Adaptive teaching machines should not be thought of as applicable solely or mainly to the learning of skills, rather than of knowledge; the feasibility of their employment in the same areas as, for example, Skinnerian or Crowderian devices, is claimed by their proponents. It is, after all, legitimate to claim that all the criteria of a 'programme' (*cf* Introduction) are complied with in adaptive instructional sequences.

A point which should not be overlooked, however, is that the response comparator function is built into a device such as SAKI; and much of the power of adaptive machines may lie in this special feature. In the acquisition of general knowledge the response comparator function could probably not be handled by the device itself but would have to be handled in some other way, e.g. by either (i) a programme writer, who would construct multiple-choice questions; or (ii) the student, who would evaluate his own responses; or (iii) a combination of programme writer and student, i.e. the latter, having responded, would be presented with a set of possible responses and be required to indicate which of these he had in fact made. (Inevitably not all responses would be foreseeable and a 'catch-all' category would be necessary. Nevertheless, whenever the responses in this category become numerous, they can be analysed to establish an improved set of response categories.)

More recently Pask and his associates have studied possible functions of adaptive devices in group learning. In particular, they have done work on an adaptive device which mediates the instruction of members of a group by one another (Lewis, 1963b); and have reported the effects of having a number of subjects, who are required to function as a group, communicate with each other via an adaptive device (Lewis and Pask, 1964). In the latter case the adaptive controller enables the members of the group to develop a common language in dealing with a given problem; improves mastery of the language by having 'transmitters' play the role of 'receivers'; and tends to produce a language which is better able to handle changes of strategy, which enables group functioning to recover more quickly following disturbance by 'misinformation', and which is less variable in communication time.

Research studies of the value of adaptive teaching machines in Service training are probably overdue. These devices might, in the first instance, prove more powerful in those training areas where a response comparator function could be built into the devices, i.e. in *craft, control, perceptual* and possibly some *intellectual skills* (see page 47). Recent work by Pask and his associates may ultimately have relevance for *management skill* and *system activity.*

Computer-Assisted Instructional Systems. (C.A.I.S.) In an experiment by Smallwood (Smallwood, 1962) subjects learned "a miniature finite Geometry" via an electric typewriter, a microfilm reader, and the Massachusetts Institute of Technology computer (I.B.M. 709). The experiment established that the programme achieved the decision structure intended by the experimenter, i.e.

it based its lessons both on the past performance of each individual while he was under instruction and on the performance of the several individuals who were instructed. This experiment is cited because it:

(a) exemplifies the functioning of a computer-based system in the manner designated as 'adaptive', and

(b) demonstrates that adaptive characteristics can be realised in a device which is controlling ideational learning, i.e. intellectual skills and acquisition of knowledge.

A considerable amount of work in America with teaching systems based on digital computers has been reported. Such systems have usually been used to teach 'intellectual' material, and their feasibility with this sort of material is fairly well established. Among the best known examples of advanced C.A.I.S. are the System Development Corporation's CLASS and the University of Illinois' PLATO and SOCRATES systems. There are at least half-a-dozen other experimental but sophisticated computer-based systems in the U.S.; though there are none yet in Britain.

It is possible that, for the higher cognitive functions at least, such computer-based systems may make the realisation of adaptive characteristics more feasible or more economic, especially if the time-sharing problem can be solved.

Research Potential of C.A.I.S. A most intriguing feature of computer-based teaching systems is that typically the subject matter is stored separately from the rules of instruction, e.g. on slides, film, or even in programmed texts and conventional books. The rules of instruction, usually a computer programme, can, for example, be varied whilst the same 'frames' are employed; or they can be used with different sets of 'frames', covering different subject-matters, or different treatments of the same subject-matter.

It seems likely that the construction, testing and revision of computer programmes embodying an instructional logic may prove more powerful in determining effective instructional procedures than current psychological theory. Furthermore, it should not be supposed that the acquisition of the skills necessary to the production of such computer programmes need present any great difficulties to psychologists and other workers in the field of programmed instruction. Programming languages, specially developed for laymen, such as FORTRAN, COBOL and ALGOL, have in recent years greatly extended the usefulness of the digital computer to business, and to scientific research in general. Comparable languages will doubtless be developed for the programming of C.A.I.S. Indeed work has already been done on at least two such languages: JOVIAL, which is being developed by the System Development Corporation, and DIALGOL, so named because its formal similarity to ALGOL is such that it may be regarded as a 'dialect' of that language. If viable specialised languages are successfully produced for computer-aided teaching systems, they may eventually make possible the discovery of effective instructional procedures of some generality.

The International Business Machines corporation, which is a leading participant in the U.S. drive towards expanding research and development in C.A.I.S., has recently developed a 'language' known as COURSEWRITER. This is a facility which allows a teacher with no special knowledge of computers to present a course of instruction through a computer and receive records of student performance. We suspect that this development may promise a breakthrough in programme writing, i.e. in the actual preparation of programmes which can subsequently be presented by 'orthodox' means. At present, programme writing constitutes the most difficult logistic problem in the widespread implementation of P.I. Any advance which would alleviate this problem should, in our opinion, be investigated as a matter of some priority.

Applicability of C.A.I.S. to Service Training. At the present time, computer-aided systems are the subject, as well as a tool, of research into training problems. Yet their potentialities for future exploitation in the service of instruction itself are already clear. For this reason we are strongly of the opinion that the most outstanding, and indeed urgent, need for advanced military research in P.I. is to provide the resources for studying C.A.I.S. in action. The main justification for this proposal is that a suitable computer-based installation would permit applied research directed towards any of the following several objectives, each of which is, in our opinion, indicative of what could become accepted practice ten years hence:

(a) Investigation and adaptation of COURSEWRITER as a possible means of compiling programmed material for P.I. using existing styles and presentation devices.

(b) Use of the installation to derive empirically the optimal instructional 'strategies' for specified training requirements and syllabi, perhaps using selection and other test results as part of the determining data.

(c) Experimental use as a control system for guiding and routeing students, in adaptive sequences, through instructional courses for which the sources of information, and training aids, are external to the computer itself. These sources may include programmed texts, simple teaching machines, as well as 'conventional' media like handbooks and illustrations.

(d) Experimental use as a control system for *groups* of students, each undergoing instruction with the aid of individual teaching machines which act as the information stores and presentation devices. The system might be extended, on a time-sharing basis if necessary, to aid the administration of a training system, e.g. by compiling individual student records and regulating the progress of the group within acceptable limits of variation.

Problems of Military Research into Programmed Instruction

It will be seen from Appendix 1 that research in the Services during the last few years has confirmed American experience that P.I. is a reliable method of instruction, and that its claim to reduce training costs is justified. Nevertheless, in spite of the vast amount of research which has been done in the U.S.A. no complete theory of instruction is available which can be used as a universal guide in designing training courses. For example, much experimental data, and the analysis of student behaviour during P.I., have failed to support the early contention that operant conditioning was the appropriate paradigm for the new medium. The purpose of this section is to outline some outstanding problems of research in this field and to indicate areas where U.K. military research might be concentrated.

Ambiguities have also arisen from a variety of inadequacies in research design. For example, it is now becoming apparent that the following factors may have rendered many experiments inconclusive:

(a) The use of single-variable experiments in what are essentially multivariate situations. There has been a lack of systematic variation of factors, such as initial attainment, which might be relevant to the learning situation.

(b) The lack of control of interactions between variables, e.g., the interaction between method of presentation and amount of instruction.

(c) The use of comparative experiments where the standards against which P.I. has been compared are unspecified, as in the description 'conventional teaching'.

The use of multivariate experiments implies a greater sophistication in the analysis of results, which in turn almost necessarily suggests the use of digital computers for data processing and statistical analysis. While the use of computers for statistical analysis is now a commonplace, their role in the simulation of learning appears to have been neglected. It remains to be seen how far field experimentation in the research on P.I. can be replaced by simulation techniques. The use of multivariate analysis, and the systematic manipulation of variables across task characteristics and student characteristics, may imply co-operation between Services in the provision of adequate student samples.

Nevertheless, in spite of these difficulties a number of experimental results are emerging which can give rise to a conceptual framework for education and training, even if this is limited to sub-areas of knowledge rather than amounting to a general theory. For example, the research which has been done on the need for overt responding shows that the original claims for P.I. were misleading, in the sense that learning will take place even if the response is covert; the universal employment of active responding is therefore unnecessary, even though it appears that there are certain circumstances where an overt response does facilitate learning. When the characteristics of these situations have been fully explored, it should be possible to build a satisfactory subtheory concerning the role of response in learning; though such a theory is likely to be far more complex and specific than the Skinnerian model which preceded it.

Thus, the military psychologist finds that there is no fruitful *general* theory on which applications for military training can be usefully based, and that to test hypotheses (whether arrived at intuitively or as a consequence of theory) demands experiments which are not easy to design and put into practice, because of the multivariate nature of the learning situation. In addition, the applied nature of his work forces him to "get programmed learning going" whilst some of the critical features of the method are still in dispute. Judgments often have to be made about the value of different types of presentation devices and programmes, and about the rules for programme writing, without the experimental results to support these decisions.

Because military training is so expensive, it is understandable that any improvement which produces a reduction in cost is likely to be pressed on the training authorities, even though it is not perfected and therefore may fall short of optimal efficiency. The danger to avoid is that these less-than-optimal improvements will be accepted as sufficient for too long, to the detriment of future innovations which may have much more to offer.

When we consider in what areas of P.I. should military research be concentrated, there are two constraints which affect the answer. In the first place, military psychologists are working in an applied field, and their work is more likely to be supported if it is seen as helping to solve military problems, even long-term ones, rather than being concerned with academic research. Secondly, since many of the problems of military training are not likely to be the direct concern of non-military research workers, it is desirable that military research should tend to concentrate on those situations which are more generally found in the Services than in civilian training situations. Military tasks cover a range of skills which are either absent or unimportant in civilian occupations. It would be appropriate, therefore, to allocate priority to studying the programming needs of skills which are specifically military, and for which there is little or no inducement in civil research organisations to develop P.I. (Some of these training areas have been noted in the preceding section.)

With these points in mind, it is possible to frame a list of topics for research which might be the province of the military psychologist rather than, say, the university research worker. For the reasons already indicated, we have not given priority to the study of stimulus-response variables (such as response mode) and programming variables (such as step size) which have hitherto formed much of the basic research on programmed learning.

Such a list might include the following problems:

(a) The development of more systematic and objective procedures for the elements of the Technology of Training. Although it is claimed that a technology already exists, several components are only developed to a rudimentary degree. For example, while it is agreed that a task analysis should precede the specification of behavioural objectives, the exact method for carrying out a task analysis is not thereby prescribed. Similarly, the translation of behavioural objectives into training syllabi is also a matter for subjective interpretation. If non-psychologists are to perform these tasks in a technical manner in the future, they would seem to need more rigorous definition and systematisation of procedure.

(b) As has already been noted in the Introduction to this report, there is no adequate method yet of describing and classifying task characteristics; and yet a thorough-going approach to training research requires more than a haphazard grouping of learning tasks, based on superficial characteristics. The provision of an adequate structure for classifying military tasks would assist the solution of military problems in the field of career structures, as well as in programmed instruction and training generally.

(c) Just as the Services have many jobs requiring special skills, so they also have unusual training situations. Thus, there is a very large requirement for training in small, remote, and scattered, units where it is difficult to use the conventional classroom method of instruction. The needs of the isolated pupil working in a technical or military situation should be considered as a particular topic for research within the Services. To some extent the Services already rely upon self-instruction in these circumstances, through the medium of correspondence courses. The value of P.I. in this context has still to be determined.

(d) Because the Services are the natural targets for manufacturers of training devices, it is likely that there will be a constant need to perform evaluative studies of new developments in training 'hardware', such as teaching machines. While these studies may not have a high status in terms of generalisable effects, they seem to be necessary if the Services are to spend money only on the most efficient devices. In the early days of P.I. it appeared to be satisfactory to ask whether, say, a machine was better than a programmed book or conventional teaching. It now seems more appropriate to ask what are the unique features of machines as compared with other media, and in what training situations will these features repay their possible extra cost.

(e) Military organisations have tended to place great emphasis on examinations to determine technical qualifications and advancement. The end-of-course examination, for example, is an integral feature of military training. There is reason to suspect that existing methods of performance assessment are inadequate for the evaluation of training or insufficiently relevant to operational jobs. For example, examiners may assume that students will differ widely in scores, even that a number will fail; and the form of the examination is determined by such considerations. Because of the need to validate programmes, it is desirable to review critically the current methods of performance assessment.

(f) There has been considerable discussion recently of a 'systems' approach to training, in which all the media of instruction (P.I., human teachers, closed-circuit TV, textbooks, etc.) are used in their appropriate roles in an integrated training environment. There is very little evidence, however, as to what are the most appropriate roles for these various media. Research is needed to delimit the parts to be played in a system (and their interrelationships) by P.I. and other methods.

We think that the role of the instructor is particularly deserving of further study. Questions about it include: Is conventional classroom teaching replaceable entirely by P.I. reinforced by tutorials, discussion groups, and more guided practical work? If something more than an invigilator is needed when students are engaged on P.I., need he be a qualified instructor? Should he have additional teaching aids, or even programmes which exploit his presence?

(g) Experience has already made it clear that self-pacing (commonly thought to be an essential characteristic of P.I.) during training courses can produce administrative problems of the first magnitude. This is so at least of establishments which are at present bound to accommodate training in groups. Yet it is not really established that unrestricted self-pacing *is* vital, even assuming it were possible to achieve in an environment where in-group pressures and interactions are present. 'Lock-step' pacing which is not governed by the responses of students is almost certainly detrimental. But if the stringency of pacing within a group can be continually adjusted by a teacher, or by a central pacing device, on the basis of feedback about responses, then it is arguable that self-pacing may present little advantage. It is at any rate an empirical question, requiring evidence, to determine whether 'adaptive' lock-step pacing can be achieved, with fully effective learning.

The topics listed above are not exhaustive of the outstanding military problems of applying P.I.; but, so far as the present generation of P.I. techniques is concerned, they appear to us the most pressing. They are, moreover, characteristic of military, rather than civilian, education and training. Finally, since the *raison d'être* of P.I. is that it will lead to lower-cost, and therefore more *efficient*, training, it would be desirable to establish the actual training costs of the present systems. Although global training costs are known as a matter of administrative routine, there is little information about the actual costs per student hour in specified training courses, and even less information about the operational cost of using badly-trained men. Although we do not regard the provision of this information as part of the psychologist's task, we should like to underline the relevance to his work of an examination of costs.

Conclusions

We have reviewed what seem to us the main 'growing points' in the theory and technology of P.I. which have practical implications for military training. The appendix which follows provides a survey of research and development projects undertaken by Service Departments to investigate the potentialities of this new medium.

It seems to us from the evidence that in some training areas at least, P.I. can be the most effective method available to us. The techniques are demonstrably suitable for teaching the academic and technical subject-matters which are the basis of Service education, and they are equally so for the informational aspects (i.e. 'job-knowledge') of operational, maintenance, and managerial tasks. Not only is P.I. an effective approach, but it is likely to be more efficient, in the sense of achieving acceptable results more economically.

Whether or not an increased effectiveness is actually attained depends primarily, of course, upon the quality of programmes. The only guarantee of their quality is that every stage of programme writing, from task analysis to evaluation, has been carried out with professional insight and thoroughness. Nor is it to be taken for granted that, once introduced, P.I. will be used with maximal efficiency. Exploiting the medium fully is partly an administrative matter, and depends upon the relative priorities attached to the following economies; all of which, but not all at once, have been realised in practice:

(a) reduced demands on highly-qualified instructors,
(b) reduction of training time, due to increased rates of learning,
(c) attainment of higher standards of knowledge and proficiency,
(d) increased 'through-put' of trainees.

The training areas noted just previously by no means exhaust the potential applications. We should expect equal gains from a systematic use of P.I. to achieve proficiency at standardised, routine, drills and sequential procedures. Clerical and maintenance routines afford wide scope in this area. We may note here that programmed devices can just as well be used in job situations where there is no absolute need for the activities to be learned. It may sometimes be more efficient just to ensure that the required procedures are carried out in a prescribed way, using the simplest practicable device for presenting a programme of instructions and guidance 'on the job'.

Another outlet for increased efficiency and effectiveness in learning could be to use whatever programmes are available in the above topics to permit servicemen to study at their home or operational stations for examinations which they currently prepare for in formal training establishments. Personnel whose needs are at present catered for by means of correspondence courses could also benefit from the substitution of self-administered P.I. An extension of these proposals would be to seek out situations where P.I. can be applied 'on the job' itself, so that controlled training takes place whilst personnel are performing their operational tasks. Continuation training at sea or in remote locations, following initial attainment of a skill under formal training circumstances, could also be expanded in this way.

It would be premature to assert comparable advantages for P.I. with respect to training in the perceptual and motor aspects of operator and workshop skills. Nevertheless, we have pointed out our reasons for believing that significant improvements in these areas are highly probable within the next few years. Research and development projects designed to hasten these improvements are as yet few in number, and exploratory in character; but gains are potentially rewarding enough to warrant an increased investment in them.

The intensive research on P.I. and its many fields of application has given rise recently to the wider concept of a 'technology of training'. Some of the component tools of this technology are already well developed. Others are primitive by comparison. We have noted that an adequate realisation of the concept entails a taxonomy of training tasks or objectives, and a classification of training techniques, each of them founded upon an acceptable psychological basis. Neither exists at the present time, however, and their construction presents an immediate research requirement.

Associated with the advent of a technology of training, but more frequently evoked as a prerequisite of P.I., is the capacity to define terminal behaviour. We have referred to the critical part played in P.I. by task and behavioural analysis in arriving at a specification both of terminal behaviour and of the content of training courses. The analysis of what really needs to be learned can lead to benefits as great, if not greater, than improvements in instructional technique. (A recent Air Force study has demonstrated, after task analysis, that no formal training course of any kind is necessary for the task in question.) However, the methodology for these analyses needs to be codified and improved. We consider that the development of such a methodology for general Service use should also become a major research objective.

Several new lines of research, arising out of but extending beyond the immediate role of P.I., have been discussed in our report. If the Services are to remain in the forefront of educational and training practice, they must encourage and assume responsibility for applied research into the improvement of current practice and the evolution of new methods designed for future needs. We have emphasised the value of preserving and extending the present urge to develop a systematic technology of training. All work which is undertaken or sponsored by the Services should be in accordance with this general objective. Particular topics can be enumerated now as likely to repay in-Service effort by showing how current practice in P.I. can be improved:

(a) Development of more suitable criteria for the assessment of programme effectiveness.

(b) Evaluation of the role of an instructor in a training system based upon P.I. Limits of profitable application of P.I. need to be determined by trial and experiment.

(c) Determination of the relation between stringency of pacing and rate of effective learning, under conditions of group P.I. Unrestricted self-pacing may not be so rewarding as to justify the cost in administrative changes which would have to accompany it.

(d) Evaluation of new and modified programming styles and devices.

All these topics can usefully be studied in the context of actual training, by combining them with the developmental work associated anyway with applying P.I. to particular training commitments. There are at least two other subjects for research which could not be merged with field applications in the same way. They entail laboratory-based facilities, complete flexibility in experimental design, and appropriate resources for data analysis. They are:

(a) research and development studies of computer-aided instructional systems. (C.A.I.S.)

(b) research and development studies of adaptive teaching machines for technical and operational skills.

We regard C.A.I.S. as the most promising of all new developments arising from P.I. Quite apart from the probable outcomes from research which have been discussed earlier, a project is justified on the grounds that an experimental system could probably allow an accelerated production and testing of new programmes for P.I. Similarly, the system could be used to devise empirically sound instructional procedures for particular purposes, and to show whether such procedures had generality for other students and subject-matters. This is not to say that we regard C.A.I.S. as an economic and practical proposition for early installation in Service Establishments. However, having noted the pace of development in the United States and having regard to the falling costs of 'hardware' in this field over the last year or more, we are disposed to believe that within a decade the C.A.I.S. could be an economic competitor to 'free-standing', semi-adaptive, devices like the Autotutor or Empirical Tutor. We should also underline the warning that commercial development of the first generation of teaching machines and programmes outstripped the supporting research on 'software'. A similar mistake need not be made again if research on C.A.I.S. is sponsored now.

Finally, we should point out that, although all the research and development work we have discussed is of direct and principal interest to the Services, a great deal of what is proposed has relevance to civil problems in both educational and industrial training circumstances. The work already promoted by the Services on P.I. has made a unique and lasting impact upon the civil authorities concerned with P.I. There is no reason to doubt that future military studies of the subject and its derivatives can be of benefit to civil developments too.

APPENDIX 1

Programmed Instruction in the Three Services

This appendix summarises work on programmed instruction in the Royal Navy, the Army and the Royal Air Force.

Programmed Instruction in the Royal Navy

THE ST. VINCENT EXPERIMENT

1. A first experiment was conducted during the winter of 1961/62 in HMS ST. VINCENT. Its objects were to test the general claims of its protagonists that P.I. has significantly more to offer than conventional teaching methods. HMS ST. VINCENT is a shore establishment where young recruits to the Navy receive their basic training. The continued study of 'school' subjects is an integral part of this training. Altogether 67 junior entrants, aged 15 years and with an average I.Q. of 112, took part in the experiment.

2. P.I. can be administered by the student himself under the fairly firm control of a teaching machine, or it can be given by means of less sophisticated but cheaper 'scrambled', or 'programmed', text-books. The recruits in HMS ST. VINCENT were divided into three equivalent groups, so that these two forms of self-instruction could be compared with each other and also with the normal system of classroom teaching. The groups were well matched with regard to their existing knowledge of trigonometry as well as level of attainment in arithmetic and algebra, general intelligence, reading comprehension, age, and educational background. A programmed course of trigonometry, capable of being presented in *AutoTutor Mk.II* teaching machines or in 'scrambled book' (*TutorText*) form, provided the common material to be learned.

3. This early experiment produced encouraging results (see Table 1). Automatic instruction proved to be quite as effective as normal human instruction in the classroom; certainly this was true of the teaching machine, though perhaps not of the 'scrambled book'. Not only was just as much trigonometry learned in the first place, but it was retained at least as well after an interval of two weeks. Persuasive, though not conclusive, evidence was revealed of a faster rate of learning among the recruits using teaching machines. On the whole, the recruits were favourably disposed towards 'automated' instruction, and a majority of them expressed a willingness to go on with the programmed method of learning. Even so, a preference was generally expressed for teaching in the conventional manner.

TABLE 1: THE ST. VINCENT EXPERIMENT

(U.S. Industries Trigonometry Programme)

	Machine Group	*TutorText Group*	*Instructor Group*
Number of subjects	23	22	22
Matching test	8·3	8·4	8·3
Post test	31·7	27·2	30·8
Retention test	28·6	24·2	26·3
Time (to complete first 75% of programme)	5·6 hours	5·5 hours	9·0 hours
Time (to complete all programme)	7·8 hours	7·9 hours	—

(Note: The post test consisted of 70 questions, the first 20 of which were used for the matching test. All 70 questions were again used for the retention test.)

EXPERIMENTS AT HMS COLLINGWOOD

4. The ST. VINCENT experiment naturally left many doubts about the practical consequences of using P.I. on a scale large enough to make a significant impact upon Naval training. Would the apparent success of programmed learning be repeated during regular, serious, training for technical personnel? Would it persist throughout courses much longer than the 9-hours'-worth of trigonometry? How formidable a task was it to programme one's own material? Further experiments with these questions in view were, accordingly, planned and carried out in HMS COLLINGWOOD.

5. Teaching-machine programmes were devised within the establishment to cover a large proportion of the basic instruction for Electrical and Radio Electrical Mechanics. Normal classroom teaching, for the three courses which were programmed, was spread over 3½ weeks of Common Training, followed by a further 1 week for 'Electricals' and 4 weeks more for 'Radio Electricals'.

6. Matched classes of up to 20 men were instructed either by means of programmed courses presented on teaching machines, or by the usual system of classroom teaching. Progress tests, written qualifying examinations, laboratory work, and expressed attitudes, were all used as comparative measures. The teaching machines, American 'AutoTutors' and British 'GrundyTutors', were used under two different conditions. 'Full automation' was represented by complete withdrawal of human teaching or guidance; nor was there any direct supervision of working with the machines. 'Partial automation', as the second condition of P.I., meant that the normal instructional staff were on hand to supervise and help, if help was sought. However, the teacher's role was 'passive' and minimal so far as supplementary aid to learning was concerned.

7. Neither of these systems of P.I. could really be judged so successful as the early promise of the ST. VINCENT experiment might lead one to expect. The existing, conventional, system was able to produce better results in the Common Training and Electrical courses; these results were by no means markedly the better, however; and the programmed course for Radio Electricals in fact compared very well indeed with conventional instruction. Some quite unexpected features emerged also. Aversion to 'machine' tuition became widespread towards the end of some courses, despite early keenness. Equally

significant was the finding that 'partial automation' as defined above, had nothing to commend it over 'full automation', so far as could be judged by all the results.

8. Clearly improvements were needed before sufficient cause for using programmed instruction consistently could be demonstrated. Two sources of improvement seemed obvious. The programmes themselves — whose quality was fundamental to success — had been subjected to trial and revision before the experiment began; but far more time and revision than had been actually available should really have been permitted. Secondly, the concept of 'full automation' in training may have been premature or even fundamentally unsound. A positive, though more than usually economic, rơle for the teacher appeared still to be vital.

9. Subsequent experiments in HMS COLLINGWOOD have taken matters to the stage where a successful integration of human and programmed instruction seems to have been achieved. The programme for Radio Electrical Mechanics (REMs), although still capable of some improvement in the light of experience, had nevertheless already shown itself able to teach up to the usual standards of classroom practice. It was therefore used again, as the core of a new system in which active responsibility for the progress and success of his class was restored to the teacher. The programme, covering all basic instruction, extended over about 40% of the training time; this was slightly less machine-time than before. Practical work in the laboratory was also distributed over about 40% of total time, similarly representing a slight reduction from normal. The remaining 20% was occupied by the instructor.

10. Three definite roles were assigned to the instructor in order to ensure that he was fully integrated into the training system. First, he was made personally responsible for his students' progress. Secondly, he was relieved by the programme of much of the drudgery normally associated with classroom teaching and laboratory work, so that he had much more time to give active help and encouragement to the students. Finally, he was assigned definite class tutorials where difficulties could be discussed, enrichment material given, and frequent revision carried out in an informal and helpful environment. Although it was expected that the quality of training would be markedly better than that found in the first experiment at HMS COLLINGWOOD, the main objective of this investigation was to 'trade' this expected improvement against any economies in the employment of instructional staff.

11. Table 2 outlines the results of this investigation. A clear-cut superiority is shown for integrated programmed instruction over all the other systems, whilst conventional programmed instruction is demonstrated to be clearly inferior to ordinary classroom teaching. Statistical analysis of the apparent differences between classes treated in the same manner have shown that the main outcome is unaffected; nor can the latter be attributed to prior differences, in that the number of trainees who could be managed by one instructor could be doubled, representing a significant potential gain in skilled manpower. The questionnaire survey and the general behaviour of the trainees revealed practically none of the disconcerting aversion to teaching machines which had accompanied the earlier introduction of programmed instruction into naval training.

TABLE 2: HMS COLLINGWOOD EXPERIMENT RESULTS

System	*No. in Class*	*Post-test*	*Lab. marks*	*Age*
1. Automated P.I.				
(a) Full i.e. no supervision	15	50·2%(1)	58·9%	16/9
(b) Partial i.e. supervision	16	51·7%(3)	56·9%	16/11
All classes		51·0%	57·9%	16/10
2. Classroom Instruction				
(a) Class 1	17	54·6%(4)	49·4%	17/5
(b) Class 2	19	68·1%(1)	50·5%	17/10
(c) Class 3	15	55·8%(1)	79·7%	16/8
All classes		60·0%	58·7%	17/4
3. Integrated P.I.				
(a) Class 1	15	65·7%(0)	60·4%	17/6
(b) Class 2	15	76·5%(0)	75·6%	17/9
(c) Class 3	16	67·9%(0)	66·5%	18/8
(d) Class 4	15	64·2%(1)	54·5%	17/4
(e) Class 5	17	70·7%(0)	70·2%	18/0
(f) Class 6	16	77·7%(0)	66·4%	17/9
All classes		70·5%	65·4%	17/10

(**Note**: The figures in brackets in the post-test column indicate how many trainees scored less than 40%. Data for 'all classes' are weighted according to numbers in the groups.)

12. The experimental course in electronics for Radio Electrical Mechanics (REMs) has continued ever since with as many as 40 teaching machines in use for this particular system of 'integrated P.I'. Since no other full-scale P.I. application has been in operation for so long with adult students, it is of interest to note the outcome, in terms of average marks obtained in the qualifying Electronics 1 (E.1) Theory examinations. Results can be shown from the first 36 classes who have been instructed under the new system; each class is made up from 15 to 18 ratings, and two classes are handled by one Instructor Officer.

TABLE 3: INTEGRATED P.I. SYSTEM IN HMS COLLINGWOOD

Successive Classes (ordinal number)	*Mean E.1 Theory Result (%)*	*Mean T.2*
1 — 10	67	111·7
11 — 20	66·5	109·4
21 — 30	62·5	110·4
31 — 36	59	109·2

Notes: (i) The corresponding average mark from other classes, taught conventionally during the period of the first 10 classes, was 63%.
(ii) Classes 1-10 include the six 'integrated' classes in Table 2.
(iii) T.2 is a measure of general intellectual standing.

13. There is a suggestion of less striking results recently than were originally obtained, so far as qualifying standards are concerned. Perhaps this is to be expected; certainly so, if novelty and the enthusiasm of early participants contributed at all to the first results. Even so, it should be remembered that the principal benefit, sustained throughout, has been a reduction in the number of Instructor Officers engaged upon the E.1 phase of REM training from 4 to 2. When this economy is taken account of, the overall experience in HMS COLLINGWOOD is encouraging: distinctly so, since the system there has after all been one of the first (if not the first) serious applications of P.I. to technical training anywhere in the world.

14. The E.1 programme itself continued in use until recently in the same form as was prepared for the original experiments. It was always accepted that improvements in its quality were possible. A revised version has in fact been produced in HMS COLLINGWOOD, together with new printed notes for students and an informative 'manual' for instructional staff. This revised programme came into practical use early in 1965, and is now used for all E.1 courses. It is particularly interesting to note that intermediate tests, and the E.1 qualifying examination itself, have also been revised in order more closely to reflect the objectives of the course. The new examination has been evaluated alongside the old one.

15. The effort required to produce an improved E.1 programme was yielded by the savings achieved in demands upon the time of professional teachers. This improvement by no means exhausted the equivalent saving, however. A notable expansion of P.I. in HMS COLLINGWOOD has now taken place, as a result of more programming; which represents an investment in the promise of still further economies, as well as more effective training. These developments can be enumerated as:

(a) Linear programmes to cover the laboratory experiments and practical work which are an integral part of REM courses. This is a pioneering venture by HMS COLLINGWOOD's staff: if as successful as early experience of it seems to promise, this application of P.I. to laboratory work will have profound implications for the practical aspects of technical training. Four programmed laboratory experiments are in regular use for Radio Electrical Mechanics. They cover the Cathode Ray Oscilloscope, Series Resonance, Diode Characteristics, and Reactance. The programmes are in linear form and are presented on Grundymaster linear teaching machines, which are located on the laboratory workbenches. Other programmed experiments are being written and validated by the establishment's staff, with the object of converting the whole laboratory course to the new method. Recently it has proved possible to save enough time on the whole electronics course (i.e. E.1 and E.2, together with laboratory work) to accommodate the fault-finding programme (c). When the programmed laboratory experiments are in full use, it may be practicable to rearrange the administration of E.1 and E.2 (see below) to accommodate individual differences in rate of learning. (Experience of the integrated P.I. courses for E.1 theory shows that savings in the time for instruction could be obtained from at least a small proportion of ratings, provided that laboratory work were programmed also to accommodate individual differences.) Still less supervisory staff may suffice then, since the instructional 'load' in laboratories will also be reduced.

(b) Another branching programme, analogous to E.1 in form, has been written and evaluated, to cover the remaining five weeks of REM instruction in electronics (i.e. the E.2 course continued from E.1). As before, the production of experimental versions of the programme on film has also been undertaken in the establishment. Now that the programmed E.2 course has been added to the earlier E.1, the entire REM training load of basic theoretical and laboratory work can be undertaken by P.I. For the first time, a programmed course lasting nine weeks has been in repeated use for practical training. It should be noted that the 'integrated' form of P.I., in which the Instructor Officer takes a unique and critical role, has been preserved. First results from this latest trial have been very satisfactory. Among 8 classes, totalling 89 men, who underwent programmed instruction for E.2 as well as E.1, the average mark in the final qualifying examination was 65%, with 8 who failed to reach a qualifying mark. The average mark for 127 men, taught by conventional classroom teaching (in 8 classes, during the same period of time), was 62%, with 17 who failed to qualify. Under the integrated form of P.I., one instructor is responsible for two concurrent classes.

(c) A need for formal training in systematic fault-finding has been recognised in the establishment, and a programmed course on the subject was acknowledged as a good approach to meeting this need. The course consists principally of a new programme on the logic and general 'strategy' of fault-finding, which has been written and evaluated in preliminary trials with REMs. The programme takes about 3 hours to work through; it is in book form, with branching and linear sequences, and is used in conjunction with a specially adapted form of the Card Index and Key system described later (paras. 63-65). The programme is followed by a series of fault-finding exercises, also devised specially in the establishment.

(d) It will be recalled that the very first experimental trials in HMS COLLINGWOOD were conducted with programmes prepared for the Common Training Course (3½ weeks), and the first week of instruction for Electrical Mechanics on Motors and Generators. A fresh approach has now been made, in the light of experience, to prepare P.I. courses to cover these commitments. (The potential gains in instructional effort are substantial in the case of Common Training; they are already beginning to be realised, as completed sections of the programme are put into effect.)

Eight 'chapters' have been prepared for the Common Training programme; some have been evaluated and are in use, and the rest should be available by the early summer. The new Motors and Generators programme is expected to have six sections.

PROGRAMMED INSTRUCTION AT HMS RALEIGH

16. In another Naval entry establishment, HMS RALEIGH, a concurrent research and development project has been in progress. This project has several objectives, one of which is to produce programmed courses in two educational subjects in which all Naval ratings must show proficiency before becoming eligible for advancement. Arithmetic is one of these basic subjects. The other is English.

17. Although the Navy has leaned to some extent upon one particular form of P.I. (the so-called 'branching' method), it is by no means wedded to this approach. Other programming formats are being tried, and new ones will doubtless be developed. In HMS RALEIGH, an experimental programme on 'Decimals' has been prepared in both 'branching' and 'linear' forms (these representing two 'focal' points in the spectrum of programming techniques), and evaluated on adult Naval recruits. The branching programme produced the more satisfactory learning, as it happened, also exceeding the achievement of classes taught normally in the classroom. Even when there was no time limit on instruction, the branching technique was demonstrably the more effective for this subject-matter which, for the majority of students, consisted largely of revision material.

18. Following these experiments, a decision was taken to programme the entire course in Arithmetic which is received by newly-entered ratings.

19. A first draft was ready early in 1965. It includes sections on Fractions, Decimals, Ratio and Proportion, Areas and Volumes, Percentages and Averages, and Graphs. Normal instruction for this Arithmetic course, none of which should (in principle) be entirely new to the recruits, is distributed over fourteen hours of Part I training. Although conceived originally in relation to the requirements of the Educational Test for Leading Rate (ETLR), the programme has been constructed to meet the new criterion of the Naval Arithmetic Grading Test. Recruits are required to achieve a Grade 7 pass at the end of Part I training. They should also, if able enough, be given the chance to achieve a Grade 5 pass, which is the required standard for advancement to a higher Rate. More is included in the course than is necessary to achieve a Grade 5 Pass in the Test, however; since the programme is intended also to provide for students who may wish to establish an adequate knowledge before moving on to Higher Educational Test (HET) studies.

20. The first stage of formal evaluation was completed in HMS RALEIGH during the summer term last year. Large classes of seamen recruits were instructed by means of a loose-leaf 'scrambled book' presentation of the draft programme. Several different ways of administering the programme were tried. The best way proved to be according to the model of integrated P.I.; when results in the Arithmetic Grading Tests were obtained showing an improvement upon 'control' data drawn from classes taught in the customary fashion. Student reactions were generally favourable to the programmed method.

21. Subsequently, the programme has been slightly revised, to an extent deemed advisable after this first evaluation, and it has been subjected to continuous test ever since. The Arithmetic programme, in its final form, is intended for use under several different circumstances, e.g. self-instruction in ships, as well as formal instruction ashore by integrated P.I. Therefore several ways of presenting the programme have been provided, and these have been subjected to experimental trials in HMS RALEIGH under each of several degrees of supervision. Since large classes, up to 50 in size (about double the usual numbers) have been the responsibility of a single Instructor Officer during these trials, it is evident that some gains in instructional productivity have already been effected, even under experimental conditions.

22. Trials of the programme have been completed with a teaching machine presentation (AutoTutors and GrundyTutors). Average rises, from the 'pre-programme' to the 'post-programme' Arithmetic scores, corresponded to an improvement from Grade 7 to Grade 5. Performance was at least as good as after conventional instruction, even when the programme was experienced as self-instruction with no more than passive supervision; it was best of all under the condition of integrated P.I., when the instructor participated actively at his discretion. Also under trial during the last six months have been two non-mechanical presentations of the programme, using methods derived from the Card Index and Key System (see para. 63, ahead). Some difficulties have been met in the preparation and administration of materials for these presentations; but preliminary results suggest that a programme which is a kind of 'scrambled-book, plus routeing-card', and which preserves a record of the students' responses, may be as effective as the mechanical presentation.

PROGRAMMES FOR HET

23. The main obstacle facing a widespread use of P.I. is to find the time and expertise for programme writing. In principle, the best procedure is to use professional teachers who have been properly introduced to the theory and practice of programming. They are then assigned to prepare courses in the particular subject-matters they know best. Nevertheless, in view of the scarce resources in programming staff, there may be some commercial courses which are relevant enough to be worth trying in a Naval context.

24. One such course appeared to be the 'Ordinary' level course in General Mathematics produced by United States Industries, Inc. (Great Britain) Ltd. Without attempting to evaluate this course (in the technical sense of 'evaluation'), a qualitative appraisal of the programme's content and style at least enables its relevance to self-instruction on the GCE/HET syllabus to be judged. Only if its general coverage and difficulty-level were appropriate for Naval purposes, would a more objective study of its effectiveness be worthwhile. Such an appraisal has been carried out in HMS GANGES. It is based upon the experience of selecting three Juniors, who would otherwise not have obtained the opportunity of studying in the establishment for a GCE examination, and allowing them to work unsupervised through the programme. The learning situation was nevertheless carefully regulated throughout the 52 hours of term-time allowed for self-instruction, using an AutoTutor machine.

25. From the detailed records of progress, test and examination results, and comments of the students, it was concluded that:

(a) although much of the programme was relevant to Naval HET requirements, a substantial portion was not. Nor was all the Service syllabus covered. Even though the style and presentation were judged to be generally good, the programme as it stood was therefore not acceptable for practical use.

(b) self-instruction with teaching machines (such as the AutoTutor used for this appraisal) was thought by the establishment's staff to be uneconomic for GCE or HET studies in a shore establishment like HMS GANGES. Given a thoroughly relevant programme, however, modelled on the lines of the U.S. Industries course, programmed instruction at sea could serve a most useful purpose in catering for the voluntary student.

PROGRAMMED INSTRUCTION AT SEA

26. The programme which has just been mentioned is one of several Naval and commercial programmes which were retained in HMS CENTAUR for a year, together with two AutoTutors. No formal schedule of trials could have been carried out in an operational carrier. Nor were the various programmes chosen for reasons other than their availability at the time and the likelihood that they might serve the interests of ratings engaged in voluntary technical or GCE studies.

27. Nevertheless, preliminary experience of P.I. at sea was obtained, even though the ship concerned and the circumstances of its commission in the Far East may not have offered characteristic seagoing conditions. Reports from HMS CENTAUR were informative, for example, about snags which must be overcome before P.I. can fulfil the useful role at sea which it ought to occupy. More sea trials, perhaps in smaller ships, are needed before firm conclusions are drawn, and several limited trials at sea have subsequently been completed. In the meantime, experience in HMS CENTAUR led to these conclusions:

(a) Provided that programmes are seen to be strictly relevant to the aspirations and interests of seaborne personnel (and this proviso is critical) potential students will welcome and use them. Free time for voluntary study may be severely limited in operational ships, however.

(b) To make the fullest use of this time (and also, possibly, to capitalise for the purposes of private study upon periods of stand-by, 'waiting', duty), it may be necessary to forgo some of the advantages of machines, which tend to be static and not immediately accessible. Portable, non-mechanical, ways of presenting programmes may be more practicable than machines, at sea.

(c) Nevertheless, wherever a classroom is permanently fitted-up so that formal instruction can take place at sea, teaching machines should take their place along with other facilities. Their design requires fresh attention, however, in order to minimize size, and the need for special stowage and maintenance.

TRAINING BY P.I. FOR OPERATIONAL SKILLS

28. The principles of learning upon which P.I. is founded are not exclusive to academic subject-matters, nor to drills and procedures. They are valid also for manual and perceptual skills. Indeed, programming techniques developed as a direct outcome of laboratory studies of how such skills are acquired. Nevertheless, there have been few serious attempts to use programmed teaching machines for the kinds of skill encountered in the handling of surveillance and weapon systems.

29. At the Applied Psychology Unit, Teddington, the last two years have seen the development of a fresh approach to two different problems of sonar operator training. In the particular cases which are under investigation, formal training by 'conventional' means was insufficient: partly due to the newness of the equipments and partly to the lack of detailed understanding of how the operating skills themselves were composed. The Unit's attempt to programme, and automate, the basic instruction has therefore been preceded by an analysis of these active and passive classification skills.

30. Both of these operating tasks require a general knowledge and understanding of what is happening to produce the various visual and auditory displays of information. Conceptual as well as perceptual components go to make up the required skill of an operator. One teaching machine which appeared at first to be well suited to the control of programmes for such a combination had to be discarded, due to its unreliability and lack of flexibility. Instead, the Unit is now engaged in preparing programmes for a modified version of the Empirical Tutor system, which accommodates visual and auditory presentation and either constructed or multiple-choice responses. Several models of the modified Tutor are being installed in a mobile 'classroom', ready for experimental trials during the present year.

31. It is hoped that this P.I. application will become a satisfactory prototype of automated training equipments for a variety of modern seaborne sonars. The experimental version is certainly promising enough to have initiated a second attempt to apply the technique to a special training problem which stems from a partly conceptual, partly perceptual, skill. An Empirical Tutor has been obtained for the establishment which is developing shore-based training equipment for computer-aided action information systems. The object is to link the Tutor to a simulator of various data displayed within the system, and to programme introductory exercises to familiarise personnel with alphanumeric tabular presentations and their association with plan-position data.

CHOOSING A PROGRAMMING STYLE AND TEACHING MACHINE

32. One of the practical problems which faces any programme writer is to decide which of the various programming techniques to adopt. Another is to choose the method of presentation: and, if a mechanised one, which particular machine. No clear-cut rules of decision-making can be offered; these problems can only be solved with complete satisfaction by the minority whose theoretical predilections permit them no latitude at all.

33. In practice intuitive and economic criteria will have to be employed in most of the programming situations encountered in the Services. However, the more empirical and comparative evidence there is, the more informed and confident can decisions be; hence it is useful to accumulate relevant evidence whenever the circumstances permit. Such an occasion occurred during 1963 in HMS RALEIGH, where it was decided that the programme on Decimals—though shorter than one would ideally choose as a reliable exemplar of P.I. —was nevertheless so well 'standardised' for its teaching merits as to make it a useful instrument for comparing different methods of presentation.

34. The objective was to allow groups of recruits who were matched on T2 scores to work through the standardised Decimals programme, in one of eight different ways of presenting it. The programme was in linear or branching form. Equivalent linear versions were prepared for use with the *Grundymaster* machine (International Tutor Machines) and the *S.S.L. Programmed Teaching Machine* (Scientific Systems Ltd.). Branching versions were prepared for the U.S.I. *AutoTutor* and I.T.M. *GrundyTutor*, and also for the *S.S.L. Machine* which is designed to accommodate both kinds of programme.

35. The experimental plan included provision for such variation in the conditions of learning as to allow eight possible conditions. In the event, the data derived from two of these conditions proved to be unreliable, and they are therefore excluded from this summary. In the following table are shown the average class *gains* in marks on the criterion test of proficiency at Decimals, obtained as a result of P.I. in one or another of the six conditions. Since the actual programmes were unchanged from those used in earlier studies at HMS RALEIGH, and the learning time was the same, it is instructive to look at these more recent results in comparison with what was found before. The last two linear and branching entries in the table indicate the earlier findings.

TABLE 4: AVERAGE LEARNING SCORES FROM VARIOUS FORMS OF P.I.

Programme Style	*Form of Presentation*	*Learning Time Allowed (minutes)*	*Learning Score (Gain in marks)*	*T.2*
Branching	Auto/Grundy Tutors (Integrated P.I.)	120	8·00	92
Branching	S.S.L. Machine	120	6·25	93
Branching	S.S.L. Machine	120	7·00	88
Branching	Loose-leaf Scrambled booklet	120	7·45	95
Branching	Loose-leaf Scrambled booklet	250	7·30	90
Linear	S.S.L. Machine	120	6·10	94
Linear	Grundymaster	120	4·90	90
Linear	Grundymaster	120	6·05	89
Linear	Numbered Cards	120	5·05	91
Linear	Numbered Cards	250	5·50	83

Notes on Table 4

(i) The two S.S.L. Branching groups were Seamen and Engineering Mechanics respectively. All others were Seamen.

(ii) The two Grundymaster groups learned under different conditions of machine presentation, one of which permitted 'confirmation' of response sometimes before the response was made.

(iii) A formal test of the reliability of these differences among groups has not been made. The trends can only be taken as suggestive, therefore.

(iv) Comparable learning scores from normal classroom teaching averaged 5·50 (i.e. for the same period, and subject-matter, with matched classes).

Too much should not be made of these results in the present context, except to say that:

(a) the decision to create a branching programme for the Naval Arithmetic programme is supported by the data.

(b) the 'integrated' system of using P.I. (i.e. with an active but new role for the teacher) appears qualitatively the most effective; although the statistical reliability of this outcome is uncertain.

(c) the advantages of machines over non-mechanical presentations are not displayed in these data so far as the branching programmes are concerned; nor is there more than marginal support for their superiority for linear programmes. An important qualification to note, however, is that the programme was brief, by practical training standards (two hours).

CONCLUSIONS FROM NAVAL STUDIES

36. The experience which Naval and other Service establishments have accumulated so far strengthens the conviction that P.I. represents a major technological 'breakthrough'. Its stress upon the clear definition of training objectives and measurement of effectiveness are representative of its claim to offer a complete *system* of training, not just a novel technique. Refinements in programme writing, and in methods of presentation and control, have multiplied during the last year or two. In the light of this progress, and from our own Naval experience of experimental applications, it is probably no exaggeration to claim that the promising improvements which are already foreshadowed could be greatly exceeded in future.

37. The scope as well as the quality of P.I. is increasing with each new attempt to apply the basic technique. For example, agreement has been reached with the establishment concerned (HMS FISGARD) to study the application of P.I. principles and technique to several subjects taught to skilled craftsmen. P.I. for workshop technology, and also for the actual learning of machine-tool operations, are among the possibilities to be tried. Also at HMS FISGARD, a new style of programming (based on the Pressey 'auto-adjunct' programme) is being drafted to cover the requirements of a Science syllabus for apprentices undergoing accelerated training. Several other training establishments, and also the Royal Naval College, Greenwich, have considered how to exploit P.I.; and programmes on special topics have already begun to be written in some of these establishments.

38. However, the practical gains which the Navy seeks are severely limited by the amount of programming effort which can be invested. The modest economies so far effected have been profitably diverted to a small expansion of programming; but the ultimate benefits would seem to justify a bigger and more formally organised *Programmed Instruction Unit;* which could assume responsibility for writing Naval programmes, evaluating them, and advising other establishments on particular applications. If it were possible to launch a formal Programming Unit, with time for advisory work in other establishments, there is every likelihood that a number of officers involved in training may be keen to undertake limited programming ventures themselves, under guidance. Many short courses of instruction in specifically Naval topics (courses in which the informational content is presented, say, in one or two hours only) are 'expensive' in the demands they make upon instructional staff. Programmes, with or without the control of teaching machines as circumstances warrant, may confer substantial benefits here. (Detailed proposals for setting up such a Unit have subsequently been accepted in principle; it is expected that a firm start will be made in the near future.)

Programmed Instruction in the Army

PROGRAMME WRITING

39. The Army's major efforts in programme writing have taken place in four establishments:

(a) The Royal Military College of Science, Shrivenham;
(b) The Army School of Education, Beaconsfield;
(c) The Royal Army Pay Corps Training Centre, Worthy Down;
(d) Alexandra Grammar School, Singapore.

40. Two programmes were produced by members of the College Staff at the level of a first degree in electrical engineering. The subject matter covered was 8 of 77 lectures on electronic engineering in a course preparing officers for technical staff appointments. The programmes deal with Triode Amplifiers, and Emission and Conduction (each topic being normally dealt with in four lectures).

41. The programmes were presented in books containing white pages (which constituted the prime path), each with corresponding red pages giving further explanation and, sometimes, corresponding blue pages giving even more fundamental help. The pages were not scrambled, each white page being followed by its corresponding red and (sometimes), blue page. The format was thus skip-branching with two or three levels of difficulty, students by-passing one or two coloured frames according to their responses. Sometimes multiple-choice responses were required, sometimes written responses. The student is, of course, his own comparator in this situation and *he* decides whether he should read the coloured remedial frames or not.

42. The programmes in their final form (after a trial with laboratory assistants as subjects) consisted of:

Triode Amplifiers: 55 white frames, 55 pink frames and 50 blue frames.
Emission and Conduction: 69 white frames and 69 pink frames.

A comparison of these programmes with conventional lecturing is referred to below.

THE ARMY SCHOOL OF EDUCATION, BEACONSFIELD

43. Aside from several short programmes, some of which have been produced as illustrative material for programming courses, the School has undertaken two programmes. The first version of a programme in military law is now complete and has undergone validation. The other programme is a fairly lengthy one which will cover the map reading syllabus for the Army's First and Second Class Certificates of Education. Both programmes have been produced on a part-time basis by RAEC officers serving at the School.

44. The programme on military law consists of 170 frames. It is a branching programme, the prime path frames having, for the most part, three-choice questions. It aims to teach officers the basic military law they would need within a unit. There are three parts. Part 1 deals with recognition of offences against the Army Act 1955, the circumstances under which it is necessary to arrest an offender, and procedure on arrest. Part 2 deals with compiling charge reports and the hearing of charges. Part 3 deals with punishments that can be awarded by subordinate commanders and by commanding officers. Each part is followed by a test and there is also a final test.

45. The programme exists in three formats:—Scrambled Book, Film (for AutoTutor or GrundyTutor), and Card Index and Key. (Reference is made to this last format below.)

46. The map reading programme is mostly linear, requiring written responses, though one of the sections so far completed has been written in the multiple-choice branching style. It is to be used along with Sheet 80 of the One Inch/One Mile Ordnance Survey (7th Series). The programme for the 2nd Class Certificate will consist in its final form of the following sections:

- Conventional Signs
- Four Figure Grid References
- Six Figure Grid References
- Further Conventional Signs
- Scales:
  - Representative Fractions,
  - Protractor Scales and
  - Scale Lines
- Relief
- Direction
- Grid Bearings
- Magnetic Bearings
- Intersection
- Resection
- Gradient
- Intervisibility
- Description of Routes
- Time and distance
- Route Cards

The Royal Army Pay Corps Training Centre, Worthy Down

47. A 600 frame branching programme has been written covering the introduction to regimental fund accounting which is normally taught in the classroom at the beginning of courses run by the Centre. It has been produced in spare time between courses by one of the Centre's instructors. This introduction consists of the basic book-keeping principles most relevant to regimental accounting procedures, namely:

Double entry recording of transactions;
Classification of transactions as 'Capital' or 'Revenue';
Classification of accounts as 'Personal', 'Real', or 'Nominal';
Opening and closing accounts;
Preparing profit and loss account and balance sheet;
The nature of assets and liabilities, 'fixed' and 'liquid' assets.

The programme is, mostly, either simple 'herring-bone' or 'skip-branching'. There are, however, several more complicated sequences as well as a built-in test with wash-back loops graduated according to performance on the test. An evaluation of the first version of the programme (see below) has been carried out. The programme's present format is 8″ x 5″ cards housed in 'Roneodex' wallets.

Alexandra Grammar School, Singapore

48. This school is for the families of Service personnel. Three written response linear programmes have been written by the staff on a part-time basis. The length of these programmes in terms of frames is not known but they provided for an average attendance of twelve 40 minute periods in the case of a chemistry programme (writing formulae, writing and balancing simple equations), for an average of 13 periods of biology (digestion in the human body), and for 24 periods of French ("Nos Voisins," 7 to 10). A report on this work states that, "at a conservative estimate", 36 hours of programming time were required for each hour of study.

49. Before administration these programmes were tried out on top stream secondary modern school subjects and "revised to minimize error rate". Presentation of the programmes was by Grolier Minmax machines. The results of an evaluation of this work are given in the next section.

COMPARISONS WITH EXISTING INSTRUCTION

50. Various comparative studies of programmed instruction have been attempted.

SCHOOL OF ELECTRONIC ENGINEERING, ARBORFIELD

51. Perhaps the first comparison of programmed instruction with existing methods in the Army was at the School of Electronic Engineering in May-June, 1962. The programme used was part of the U.S. Industries basic electronics TutorFilm and was presented to REME craftsmen by AutoTutors. The report on this work concluded, inter alia, that the programme taught as well as a good artificer instructor who took a control group through the same subject matter, but it also points out that, despite attempts to match the groups, it subsequently turned out that "the division of ability was not in fact equal".

THE ROYAL MILITARY COLLEGE OF SCIENCE, SHRIVENHAM

52. In the 1963 Lent Term the College compared the effectiveness of the programmes in Triode Amplifiers and Emission and Conduction described above, with conventional lecturing. Thirty-odd officers in their late twenties or early thirties were divided into two groups. 'Group A' was assigned to supervised study of the programmed text on Emission and Conduction, 'Group B' attended four lectures, each of which was supplemented by a sheet of problems for private study. Time spent on lectures, on the programmed text and on all private study was recorded for each officer. Following a test on Emission and Conduction the methods were reversed between groups, i.e. Group B was assigned to the programmed text on Triode Amplifiers and Group A to lectures. This second half of the experiment was similarly followed by a test on Triode Amplifiers. Thus, in this interesting 'cross-over' experimental design, each subject is his own control — a feature which one might wish to see more often in experiments with programmed learning.

53. However, with regard to the ability of the two groups to assimilate two different subject matters, the matching data cited in the report of this experiment is rather limited, each officer being rated on a three point scale of previous knowledge. The report concludes, inter alia, that in terms of time and achievement on post tests, the programmed texts were comparable to conventional lectures.

THE ROYAL ARMY PAY CORPS TRAINING CENTRE, WORTHY DOWN

54. An evaluation of the programme on regimental fund accounting described above was carried out by the Army Operational Research Establishment in April, 1964. The subjects were taken from two groups—apprentices and recruits. The classroom instruction was undertaken by an experienced instructor, possibly of above average ability. The results of various pre-tests and post-tests are summarised in Table 5.

TABLE 5: REGIMENTAL FUND ACCOUNTING

Pre- and Post-Test Means

		Programmed Instruction		*Classroom teaching by RAPC Instructor*	
		Apprentices (n = 6)	*Recruits (n = 6)*	*Apprentices (n = 6)*	*Recruits (n = 6)*
Pre-Tests	Raven's Matrices (1938)	47·7	49·7	46·8	48·2
	Accounting -Principles (Multiple Choice Test)	17·7	6·7	16·5	7·0
Post-Tests	Accounting -Principles (repeat of Pre-test)	26·8	25·3	24·0	27·1
	Accounting -Definitions (written response)	27·0	31·0	21·8	31·8
	Accounting -Practical	61·5	58·6	42·1	70·6

55. It will be noted that there is an apparent interaction between the two groups and the two methods of instruction, apprentices tending to score higher under programmed instruction, recruits higher under conventional classroom instruction by an RAPC instructor. However, only one of these apparent differences, that between apprentices on the practical accounting test, is statistically significant.

ALEXANDRA GRAMMAR SCHOOL, SINGAPORE

56. The programmes written by the School staff and described above were evaluated, together with a commercial algebra programme, on first form students in the latter half of their second term, i.e. March-April, 1964. (The commercial programme was TMI Grolier Algebra I, i.e. simple equations.) Thirty-six pairs of students, matched in terms of sex, intelligence and attainment in examinations at the end of their first term (rank order) were divided into conventional classroom instruction and programmed instruction groups.

57. Table 6 shows the comparative achievements and attendance of 32 of the 36 pairs for whom data was complete. Three of the differences between methods are significant, two in favour of programmed instruction (Biology and Chemistry), and one in favour of conventional classroom teaching (Algebra).

TABLE 6: ALEXANDRA GRAMMAR SCHOOL. POST-TEST MEANS, AND AVERAGE ATTENDANCE OF THE TWO MATCHED GROUPS (N = 32 IN EACH CASE)

Subject	*Programmed Instruction*	*Conventional Classroom Instruction*	*Average Attendance (40 minute periods)*	
			P.I. Group	*C.C.I. Group*
French	37	34	24	26
Algebra	41	47	14	13
Biology	48	31	13	12
Chemistry	77	54	12	12

OTHER COMPARISONS OF PROGRAMMED INSTRUCTION WITH CONVENTIONAL CLASSROOM INSTRUCTION

58. An experiment was carried out by the Army Operational Research Establishment at the Army Apprentice School, Arborfield, in October and November, 1963. The main object of this experiment was to compare presentation of a trigonometry programme by AutoTutors with the same programme presented via a new and fairly inexpensive device, of which more is said below. However, the experiment had a secondary objective — to compare programmed instruction with instruction by an experienced RAEC officer. This officer taught two groups, one twice as large as the other. Paradoxically, the smaller group had the lower post-test score, though the difference between the two groups and, indeed, the differences between all the groups (programmed instruction and conventional classroom instruction) is statistically non-significant. Table 7 summarises the matching test and criterion test data for the four groups in this experiment.

TABLE 7: ARBORFIELD APPRENTICE SCHOOL. PRE- AND POST-TEST MEANS
(U.S. Industries Trigonometry Programme)

Group	*n*	*A.H.4 (General Intelli-gence)*	*N.S.6 (Reading Compre-hension)*	*Arith./ Algebra*	*Geom./ Trig.*	*Trig. Post-Test*
AutoTutor	16	80·63	51·25	12·75	6·94	28·63
Card Index and Key	17	79·82	51·94	13·29	7·82	28·12
Classes taught by RAEC Officer	14	80·21	52·57	14·21	7·79	29·71
	6	80·17	50·83	14·17	8·00	25·17

59. More recently the ASE programme on Military Law has been evaluated on RAEC Officers and RAPC Officers and Warrant Officers. The main findings, which indicate that the programme is probably more efficient than conventional classroom instruction, are given in Table 8. Again the Card Index and Key System was used as well as a teaching machine (the GrundyTutor).

TABLE 8: MEANS FOR COMPARATIVE AND CRITERION TESTS — MILITARY LAW PROGRAMME

Variable	*R.A.E.C. Subjects*		*R.A.P.C. Subjects*	
	Grundy Tutor	*Card Index and Key*	*Grundy Tutor*	*Conventional Classroom Instruction*
	(n = 15)	*(n = 15)*	*(n = 12)*	*(n = 10)*
AH4 (General Intelligence)	97·80	94·40	92·08	81·40
Black's Test (Reading Comprehension)	41·93	46·73	34·08	30·70
Military Law Pre-Test	43·93	42·20	53·58	38·50
Age - months	365	399	526	471
Military Law (a)	65·93	67·33	70·58	60·40
Post-Test (b)	66·35	66·35	66·35	66·35
Overall Time (a)	96	150	132	265
(Minutes) (b)	95	154	128	246

(a) observed mean. (b) observed mean adjusted to take account of initial differences between groups.

60. Finally, an evaluation was undertaken by AORE of the U.S. Industries Slide Rule programme. Subjects in the experiment were officer cadets in their second term at the Royal Military Academy, Sandhurst. Interpretation of the data is complicated by important differences between the content of the programme and R.M.A., Sandhurst, teaching of the slide rule. The programme produced unfavourable reactions to P.I. in a majority of the subjects.

AN INEXPENSIVE SYSTEM FOR BRANCHING PROGRAMMES

61. Those responsible for armed services education and training are frequently faced with groups which are heterogeneous with respect to intelligence, existing relevant knowledge and skills, etc. 'Branching' devices like the Auto-Tutor are attractive because of their capacity to adapt the material presented to such individual differences. Such devices are also very expensive.

62. The early work in the Navy demonstrated that a book format such as the TutorText is no substitute for a machine like the AutoTutor. Experiments have been carried out by AORE with an alternative system for branching programmes. This system is fairly cheap and has many of the advantages of the machine as well as some of its own.

63. The system has two components:—a card index containing the instructional information — the 'frames'; and a key which indicates the route through the programme to be taken by the student. The key in our experiments consisted of a card on which was printed a matrix. The rows of the matrix correspond to the frames in the programme, the columns to alternative responses. The student responds to the programme by shading appropriate cells in the matrix with a soft pencil. The effect of shading is to reveal the image of a number which is embossed in the Card but hidden by the top layers of paper. This is the number of the frame which should next be studied.

64. It is clear from Tables 7 and 8 that the attainment of matched groups with this system is as good as with the AutoTutor and GrundyTutor machines containing the same programme on films, with one proviso. When, as in the evaluation of the Military Law programme, the length of a session for each student is determined by the time he takes, working at his own pace, to reach a previously fixed point in the programme, then the Card Index and Key System takes longer than the machine.

65. The system has several advantages and disadvantages vis-a-vis the machine which were not all obvious until it had been used experimentally. To summarise these, there are three main disadvantages having to do with:

(a) *Cheating.* The Card Index and Key System is cheat-revealing rather than cheat-proof. The machine can prevent undesirable back-tracking (e.g. looking up the answers to 'built-in' test questions). This the system cannot prevent, but only make difficult. However, to the extent that filmed programmes depend on the machine's error counter, machines are strictly only cheat-revealing devices.

(b) *Storage and Capacity.* Programmes stored on cards will obviously make far greater demands on storage space than will programmes stored on film. Similarly, the capacity of the machine greatly exceeds that of inexpensive card indexes.

(c) *Changing the Programme.* This is much less convenient than with the machine.

The advantages may be summarised as follows:

(1) *Low Cost.*

(2) *No power requirement.*

(3) *Random Access.* A path can go from any one frame to any other frame. No machine could achieve random access so inexpensively.

(4) *Programme Revision.* The record of choices left by each student on his key provides data for programme revision; i.e. data on which frames give general difficulty. This information is not provided by the machine. Furthermore, replacing frames or whole sequences is easy with a card index. Filming positively discourages continuous modification of the programme (an ideal advocated by many and practised by few).

(5) *Human Teacher Participation.* A combination of human teacher and programmed instructional device is probably superior to either alone and the complete absence of human support is likely to prove unpopular. Because the system is cheap, the problem of making economies in teaching staff is avoided. However, the whole question of the role of the teacher in a class under programmed instruction is deserving of further study. Presumably, if the teacher is to *participate* and not merely invigilate, he needs feed-back of information on each of his pupil's movements through the programme. Apart from telling him the frame reached, machines only indicate (and not always reliably) the number of 'errors' so far made. What the human teacher most needs to know is not just how many, but *which* errors have been made, *which* concepts have given a particular pupil difficulty. The record of choices left by each pupil in his use of the key goes some way towards providing this information.

66. In conclusion, the system may be a useful compromise for newcomers to the field of programmed learning because it permits flexible, even sophisticated, programming without committing them to much expense. Furthermore, the inevitable faults of the programming novice can conveniently be put right.

FURTHER RESEARCH

67. In the future, an investigation is planned into the contribution of 'branches' to learning. The programme to be used will be Thornhill's "Waterloo Campaign".

68. It is also hoped to study adjunctive programming, possibly using the Common Core electronics texts, with and without the supporting control of tests indicating specific sections of text for revision.

CONCLUSIONS DRAWN FROM ARMY WORK

69. Glittering prizes are offered to those who introduce programmed instruction into educational and training situations. There has been no shortage of good reasons why programmed instruction must be, in principle, superior to conventional classroom instruction, and indeed the first empirical studies in the armed services seemed to promise dramatic improvements in learning rate. More recent work, however, has tended to indicate (as do most of the foregoing comparisons in Army establishments), something nearer to parity between programmed instruction, on the one hand, and conventional classroom instruction on the other.

70. This tendency may, of course, have many contributory factors and it is probable that some of these are, as yet, little understood. However, two possibilities immediately suggest themselves. As comparative studies become more numerous, there may be a tendency for teachers of the control groups in such studies to be more effective, either because teachers of above average ability are deliberately sought to set programmed instruction a rigorous test, or because the teachers, understandably, engage in herculean efforts to beat the programme. To the extent that this is true the findings of recent studies are grounds for optimism rather than disenchantment.

71. A second possible cause for the recent findings of experiments with programmed instruction is more disturbing. It is that the standard of programming currently being achieved is failing to exploit to the full the possibilities of programmed learning. It will be clear from the foregoing account that such programming as is being undertaken in the Army is usually on a part-time basis and is frequently in addition to regular duties. It is very likely that time constraints may be leading programmers, whose task can be agonising in the best working conditions, to neglect the internal validation of programmes; i.e. try-outs with individuals from the target population tend to be perfunctory, and drastic revision of programmes rare. As a result, programmes are probably too teacher- or instructor-orientated; and there may be important discrepancies between an approach based on the teacher or instructor's preconceptions and a truly student-centred approach, as has been shown by Mager (1961) in the case of sequencing. With regard to programming style, efforts have almost all crystallised, possibly prematurely, into either multiple choice branching programmes, or constructed response linear programmes. With few exceptions the style chosen seems to depend on the programme writer's predilections, rather than, e.g. on the responses specified in the terminal behaviour, or on the degree of heterogeneity of the target population.

72. Finally, more extended studies of programmed learning have yet to be carried out in the Army. Most programmes so far completed have been fairly short. The Army School of Education's programme on map reading will probably be the first long programme to be introduced. It is only by the introduction of such longer programmes that the problems of integrating programmed instruction into Army educational and training situations will be solved.

Programmed Instruction in the Royal Air Force *

73. Initial investigations were carried out by the Royal Air Force School of Education and the Research Section at Headquarters, Technical Training Command. In order to prevent any duplication of effort, the School of Education agreed to confine its efforts to the problems of programme writing, whilst Technical Training Command Research Section evaluated the application of programmed learning and teaching machines in some of the problem areas of technical training.

THE YATESBURY EXPERIMENT

74. The first evaluation was carried out at No. 1 Radio School, Royal Air Force, Yatesbury, in the Autumn of 1961, using the branching programme on Trigonometry written by Norman Crowder and Grace Martin. Twenty-nine students were taught by means of teaching machines, and a control group of thirty students of comparable aptitude and educational attainment were taught by conventional classroom methods. At the end of the experiment, it was found that there was no real difference in the achievement of the machine-taught group and the classroom group—except that the teaching machine group reached their standard in only 39% of the time. A retention test was given three months after the completion of the experiment, and no significant difference was found between the scores of the two groups (see Table 9).

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* This section is partly based on a note describing Royal Air Force experience with P.I. written by Squadron Leader I. K. Davies, R.A.F. (Davies, 1964c.)

TABLE 9: ROYAL AIR FORCE YATESBURY EXPERIMENT

Criterion Scores for Machine and Classroom Groups

	AutoTutor Group				Classroom Group			
			Time				Time	
	Post-test	Retention Test	Formal Study	Formal Plus Private Study	Post-test	Retention Test	Formal Study	Formal Plus Private Study
Mean	59%	68%	5:30	5:53	58%	66%	11:00	14:23
N	29	22	29	29	30	23	30	30

THE MELKSHAM EXPERIMENT

75. Since the Trigonometry programme used at Yatesbury was relatively short, the results of this experiment could hardly be generalised to most RAF training courses, and it was therefore decided to evaluate teaching machines over a longer period of instruction. Accordingly, a further experiment was carried out at No. 12 School of Technical Training, Royal Air Force, Melksham, in 1963. A battery of AutoTutors was used to teach sixty-two Electrical and Instrument Fitters the fundamentals of electronics. The portion of the syllabus which was used in the experiment extended over six weeks, and covered DC and AC Theory. During this time about half of the students' time was spent in the classroom, while the remaining time was either spent on laboratory work or in the workshops. However, the programme only covered the classroom instruction phase, so that the laboratory and workshop instruction was carried out in the normal manner.

76. The machine group was matched for attainment in mathematics and science with a conventionally taught group of fifty-three students. A blind control of seventy-six students — who were unaware that they were taking part in the experiment — was used for comparison purposes. The results are summarised in Table 10. It will be seen that there was no real difference between the classroom-taught group and the machine-taught group as far as total learning time and retention scores were concerned, but that there was a real difference in the time spent on private study and in the post-test scores. The post-test scores suggest that as far as actual attainment was concerned, the classroom group was superior in their grasp of the factual content of the examination. In a test for understanding and depth of knowledge, however, the machine group was significantly better.

TABLE 10: ROYAL AIR FORCE MELKSHAM EXPERIMENT 1963

	No.	Matching Test (Maths. and Science)	Post-tests		Total Time	Retention Test	Time spent in private study
			Knowledge	Depth			
Classroom Group	53	64%	75%	53%	77 hours	57%	28 hours
Machine Group	62	64%	67%	68%	75 hours (68 hours without revision)	59%	16 hours
Blind Control	76	65%	78%	56%	—	—	29 hours

77. The results are not so dramatic as those obtained at Yatesbury, but a part of the explanation is contained in the differences between the programme and the normal school syllabus. At least three questions in the first post-test (i.e. equivalent to 10% of the marks) were not taught by the programme. There is evidence which suggests that if the programme and the syllabus had been identical in content, then the machine-taught students would have reached the same standard in a shorter time than the classroom students.

78. A number of general conclusions can be drawn from the Melksham investigations. First, the majority of the students were quite happy to use a teaching machine for about four hours each day on a single subject for several weeks at a time, whereas six or eight hours each day appeared to be excessive. However, during the time that they were using the machines very little support was required of the instructor, although they prefererd to have an instructor available who could answer questions and get them out of difficulties. Secondly, since the experiment suggested that machines could teach at least as well as conventional instruction, a case can be made for using programmed learning on economic grounds alone. Savings could be made either by increasing the productivity of the teacher, or by decreasing the time during which the students are being trained. Lastly, one particular problem that the Melksham experiment highlighted is to be found in the difficulty that was experienced in allowing students to progress at their own particular speed. It is not satisfactory to insert a programmed phase into the middle of a non-programmed course, since the resulting administrative and organisational problems are almost insoluble. It is also difficult to provide students with a strong enough incentive to complete the programmed phase in the minimum time of which they are capable.

79. The work at Melksham using AutoTutors was continued in 1964. The findings indicate that, using a programme more similar in content to that of classroom instruction, the attainment under programmed instruction was increased.

FAULT-FINDING TRAINING

80. An opportunity occurred in March, 1963, to explore the use of programmed devices in an experimental fault-finding course, which was designed to teach a class of eleven Royal Air Force mechanics to diagnose faults to component level on an airborne radar equipment. Five types of programmed instruction were employed: workbook exercises, punchboard exercises, scrambled texts, 'cheatproof' scrambled texts, and a linear programme used in a home-made teaching machine.

81. It was found that a class using the workbooks needed the full supervision of an instructor, who also corrected student exercises and provided remedial teaching. The punchboard was easy to prepare and use, and the students' attitudes were generally favourable towards it. A combined use of workbook and punchboard left the instructor with the sole role of providing help and guidance. The majority of the students thought that the scrambled texts were useful, but they would have preferred less of them; indeed, some of the students preferred the punchboard to the scrambled texts. Scrambled texts with

'cheatproof' devices functioned satisfactorily, although a number of students complained that the device was an unnecessary complication. Generally, the students were not overwhelmingly impressed by the linear teaching machine, and they objected to the small steps in the programme. This trial demonstrated that programmed devices could be used in the teaching of fault-finding, and that simple devices can simulate some functions of complicated electronic equipment. Since the provision of sufficient electronic hardware for training purposes is expensive, the use of P.I. in this area of training has much to recommend it.

THE HALTON EXPERIMENT

82. In November, 1964, an experiment was mounted at Royal Air Force, Halton, where one hundred and fifty-eight apprentices worked their way through a mathetics programme on the "Principles of Automatic Car Transmission Systems". The students were divided into five matched groups on the basis of a pre-test, aptitude tests, age, trade, and marks in Mathematics, Science and English. Four editions of the programme were prepared. Group 1 used the full mathetics programme, Group 4 used a special edition consisting of only the main teaching pages of the programme — that is to say, the programme used by Group 4 was one-third the size of the programme used by Group 1 since all practice and revisionary frames had been removed. Group 2 used an edition which consisted of only the main teaching pages (demonstration exercises) and prompting frames, whilst Group 3 used an edition which consisted of the main teaching pages and criterion or key frames (release exercises). Students worked through the programme as given, completing progress tests at the end of each of the four sections into which the programme was divided. When they had completed the programme, the students answered two post-tests — the first an objective one using multiple choice questions, and the second a subjective one using open-ended questions. An attitude survey was also administered in order to determine the relevant ease or difficulty of the programme.

TABLE 11: A SUMMARY OF THE FINDINGS OF THE ROYAL AIR FORCE HALTON EXPERIMENT

	Mean	Group 1	Group 2	Group 3	Group 4	Group 5
N		36	36	36	36	14
Pre-test	20·4%	19·7%	20·3%	22·2%	20·7%	20·3%
Post-tests						
Objective	93·0%	94·4%	91·8%	93·9%	92·0%	26·9%
Subjective	87·7%	89·4%	86·7%	88·9%	85·5%	—
Retention tests						
Objective	68·5%	70·9%	69·1%	70·1%	63·4%	27·1%
Subjective	71·5%	73·5%	71·8%	71·3%	69·2%	15·3%
Transfer	47·8%	48·6%	51·9%	44·7%	45·9%	4·0%
Time to complete Programme	182 mins.	220 mins.	183 mins.	184 mins.	140 mins.	—

83. The results of the experiment are outlined in Table 11. There was no significant difference between the achievement obtained by any of the four groups, measured either by the objective or subjective post-tests. The practice effect of completing the same examination a number of times is indicated by the results obtained by Group 5, who — whilst they did *not* work through the programme — completed every examination. There was a significant difference, however, in the time taken to complete the programme, since Group 4— having far less material to work through — completed the programme in a much shorter time. Retention tests were administered five weeks after the programme had been completed. The objective test was the same one that had been used as a pre-test and as a post-test, the subjective test was the same examination paper as the subjective post-test, whilst the transfer test was a new paper specially written for that phase of the examination. The main aim of the paper was not to test material that had been directly taught by the programme but to test the ability of the students to apply what they had learnt to new and novel situations.

84. It is still too early to draw too many conclusions about the Halton study, and the experiment will be repeated with a less able group. There are a number of lessons, however, that can be drawn, particularly from the point of view of programme writing. Regardless of which edition the students used, the programme was reported to be interesting and challenging. Since the programme used by Group 4 was one-third the size of the programme used by Group 1, one can conclude that the shorter programme — regardless of the very steep gradient of its material — was the more efficient instrument. Furthermore, since the overt responses required by the students working through the shortest programme were in every case copy responses, it would seem that such a response form need not be as inefficient as has been so often suggested.

FURTHER EXPERIMENTS

85. Three further experiments at Royal Air Force, St. Athan, Royal Air Force, Newton, and Royal Air Force, Compton Bassett, must also be mentioned.

86. The Temac Algebra programme was used with Boy Entrant trainees at St. Athan. The general conclusion was that the students using the programme obtained a result equivalent to that obtained by normal methods with very much less instructor supervision. This was achieved in spite of the fact that the Temac programme covers a more extensive syllabus than the normal course. However, later classes complained that the Temac programme was uninteresting, and asked to cease work on it. A scrambled programme has been accepted by the students with more enthusiasm.

87. Two linear programmes, "Basic Electricity" and "Basic Electronics", published by McGraw-Hill, were used to teach a class of post-graduate engine and airframe fitters at RAF Newton. The experiment showed that programmed books could be used successfully at a considerable saving of instructor time, and that the use of linear programmes in book form over a six week period was received with enthusiasm by the students. It thus counterbalances the implication from the St. Athan trial that linear programmes are unsuitable

for extended periods of study. The experiment also demonstrated once again the difficulty of using a programme not entirely similar to the normal syllabus of the course.

88. The need to programme a complete course led to the selection for this purpose of a one week post-graduate course on a communication equipment at RAF Compton Bassett. A task analysis of this course was carried out as a first step in writing the programme. The analysis revealed, however, that such maintenance work as was necessary for the equipment could be learnt on the job, and no formal training course was required. Accordingly the programme was abandoned and the course disestablished.

PROGRAMMED INSTRUCTION AT THE ROYAL AIR FORCE SCHOOL OF EDUCATION

89. Whilst all this experimentation was taking place, the Royal Air Force School of Education was concerning itself with the difficulties of writing and presenting programmed materials to students who were not inherently bookish or intellectual in their approach to learning. It was felt that many teaching machines force programmers to rely far too much on the written word, whereas many relationships and discriminations ought to be discovered by the students themselves through observing actual working instruments and equipments. The final result of this investigation was the invention of the Empirical Tutor, now available on the commercial market and used by a number of universities and industrial organisations. The machine, which uses a linear or simple branching programme and employs constructed response and multiple-choice response modes, automatically controls a whole range of training equipment. The student is thus encouraged to take a far more active role in the learning process by being enabled to make full use of his powers of observation and deliberation, evaluation and judgment. In this way, the teacher's fundamental role in the teaching process is not usurped; instead, he is freed from many of his routine and tiresome chores so that there is increased time available for inspirational teaching and individual tuition.

90. Once the problem of designing a completely flexible teaching machine had been tackled, the difficulty of constructing and writing programmes for it became even more difficult — the very flexibility of the machine created even more problems! Finally, a complete system of programme construction was developed and subsequently published as "Programmed Learning in Perspective". In this system, programming is conceived as a sixfold process: study of the syllabus, reconciliation of the syllabus with the needs of students and with the specific aims of training, preparation of a scheme of work, collection and organisation of material, construction of a matrix and flow diagram, and the final frame writing.

91. In following through these stages, the subject material is fashioned and structured for learning by the target population for whom the programme is being written. Relationships between units of information are recorded on a matrix, which indicates an order in which the material should be presented, the points at which branches should diverge and converge, the position of revisionary sequences, and the number of frames necessary to teach each rule

and establish each concept. Whilst there are many ways of writing a programme, it has been found that this scheme helps to prevent an unnecessary proliferation of frames, reduces the amount of time necessary in preparing and writing programmes, and helps overcome some of the problems of training programme writers.

CURRENT ROYAL AIR FORCE STUDIES

92. The period of initial investigation concerned with evaluating programmed learning in the Royal Air Force is now at an end. A new phase is just beginning. This consists of an experimental application of programmed learning to some of the current training tasks on a restricted and discriminate basis, with the writing of programmes by teams and individuals organised by the use of a network analysis. Four projects in the use of P.I. are in progress:

(a) The Science A & B syllabus for the RAF Education test is being programmed for the use of airmen studying for this examination at operational stations.

(b) Commercial programmes in algebra and mathematics are being made available for airmen taking the GCE "O" level mathematics examination. The algebra programme is in book form, whilst the mathematics programme is presented by a machine.

(c) A one week post-graduate course on transistors has been prepared for presentation both by scrambled book and by teaching machine. The programme will be used on operational stations by students who would otherwise have attended a training school for this course.

(d) Teams of programme writers are being set up to prepare programmes for technical training in four areas. When complete, these programmes may be used either at the student's home station or as a replacement for conventional instruction at the training school.

93. The application of programmed learning to these Royal Air Force training situations holds the promise of improved training either by reducing existing training costs, or by increasing the level of students' attainment, or by providing instruction in areas where it has been difficult to provide conventional instruction. While there are many problems of an administrative and organisational character to overcome, the successful use of P.I. in these situations would result in more efficient and effective training.

Towards a Technology of Training : A Classification of Training Areas & Instructional Methods

INSTRUCTIONAL METHOD / TRAINING AREA	Self-Instructional/Student-Centred Methods					Instructor-Centred Methods					Equipment-Centred Methods		
												Simulators	
	Programmed Instruction (a)	Correspondence Courses Workbooks and Private Study (b)	Learning "on the Job" (c)	Role-Playing and Group Dynamics (d)	Expedition Training (e)	Classroom Teaching with Directed Activity (f)	Supervised Activity and Practical Work in Labs./Workshops (g)	Learning in the Occupational Setting with formal Instruction (h)	Illustrated Lectures and Closed-Circuit TV (i)	'Guidance' Training (j)	Procedural Trainers and Synthetic Devices (k)	Using real Equipment (l)	Using Synthetic devices or computers (m)
1 **Physical Fitness** a in normal climates b in extreme climates.													
2 **Procedural and Routine Skills** Sequences of fixed, discrete, 'open-loop', actions, eg. switching-on drills for equipments clerical and supply routines, manual handling procedures dismantling and assembly operations													
3 **Perceptual Skills** Operator tasks involving mainly perceptual activity e.g. radar sonar and other monitoring tasks photographic interpretation, aircraft recognition.													
4 **Control Skills** Serial tasks, involving continuous, non-repetitive error-actuated ('closed-loop'), actions a **Craft** using hand/machine tools for production b **Operating** tracking, guiding, piloting, or driving in a man-machine system c **Coding**: typing shorthand teleprinting													
5 **Acquisition of Information** Learning theory, facts or background knowledge about equipments or operations including those covered by other categories													
6 **Intellectual Skills** Exercise of reasoning, judgment, inferential thinking e.g. electronic fault-finding, navigation													
7 **Character-Building** Development of self-reliance initiative, resourcefulness													
8 **Managerial Skills** a. **Leadership** persuasion of others to action by means other than direct orders b. **Decision-making** tactical deployment of weapons resources, and personnel, during action c **Committee and Staff Activity** evolution of policy, administrative control													
9. **Identification with the Group** Emergence of positive attitudes towards aims and conditions of Service life and appropriate behaviour e.g. within sub-units (platoon, mess-deck) major units (air station regiment, ship), Service as a whole													
10 **System Activities** Co-ordinated operational work undertaken in small man-machine groups, where (by definition) there is no redundant member, e.g. aircrews, tank crews fire-control and weapon teams													
11 **Operational and Combat Formations** Activities of formal units, where (by definition) loss of individual members can be sustained e.g. Marine commando infantry platoons													

NOTES: i. This classification is provisional
ii. Training Areas may also be taken to represent general objectives of military training They are defined in terms of human skills
iii. Training Areas 1 to 8 refer to individuals Nos 9 to 11 refer to groups

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MINISTRY OF DEFENCE

PROGRAMMED INSTRUCTION IN THE BRITISH ARMED FORCES

A Report on Research and Development

by

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Introductory Note

This report was submitted in May 1965 by a Working Party set up by the Advisory Panel of Service Senior Psychologists to enquire into research and development issues relevant to Service training, with the following terms of reference:

> " To examine the current extent of research into Service training, starting with Programmed Instruction. To report on progress and likely trends and to recommend to the Advisory Panel of Service Senior Psychologists such measures as should be taken to ensure that future problems are identified and investigated."

Because of the potential interest of the contents of the report to those concerned with problems of education and training outside the Services as well as within, general publication was considered worthwhile.

Outline of the Report

Programmed Instruction (P.I.) is often, but not necessarily, associated with teaching machines. It is essentially self-instruction; but is designed to allow more effective and economic training, rather than simply to replace human instruction. Since its introduction in this country only six years ago, it has developed into a powerful new method, applicable to a wide field of military education and training.

Instruction can be said to be programmed when:

(a) There is a clear statement of exactly what a man will be able to do at the end of it.

(b) Everything which has to be learned is broken down into discrete but associated items, and is taught through a sequence of steps ('frames').

(c) Trainees follow an actual sequence of frames which is determined for them according to their individual needs on the one hand, and to the rules of programming technique on the other.

(d) Trainees are actively responding all the time, and there is a continual and immediate check on their accuracy and progress.

(e) Subsequent steps in instruction are never taken until success has been demonstrated at preceding items.

The Service departments have been pioneers in the United Kingdom with respect both to programme writing and to studies of productive ways of using P.I. Much of their work has been described in official reports and journal articles. However, in order to give a concise account of this research and development work, Appendix 1 of the present report summarises the experiments and programme-writing activity carried out by each Service between 1961 and 1965.

So far most applications of P.I. have concentrated on scholastic subjects. However, its principles are not confined to this area. They are equally valid for manual and perceptual tasks. Current service applications in fact cover a wide spectrum, from the technical training of electronic technicians to courses on managerial skill.

Early in the development of P.I., it was realised that efficiency of training is a function of many factors; the quality of instruction is only one of these. Practical applications of P.I. have given rise to the wider concept of a 'technology of training'. The nature of this technology is discussed in the report. It includes the systematic derivation of training objectives from the study of operational task requirements; the assessment of knowledge and ability among potential students; specification of contents, methods, and materials, of training courses in the light of the foregoing; and, finally, the assessment of training efficiency in terms of performance standards and cost-effectiveness.

Future research and development trends in P.I. are discussed in some detail. Among developments already under way (and, indeed, well advanced in the United States), the Working Party points to computer-assisted instruction as likely to make an impact in due course, e.g. in providing instruction which is adapted to individual differences, in assisting human instructors to 'programme' their courses, and in helping to identify the best instructional 'strategies' for particular training needs.

A widespread Service use of P.I. offers potential savings in training costs due to factors such as:

(a) reduced demands on highly qualified instructors,

(b) reduction of training time, due to increased rates of learning,

(c) attainment of higher standards of knowledge and proficiency,

(d) increased 'through-put' of trainees.

While all these gains have yet to be achieved in a single project, the growing use of P.I. as a routine training method increases the likelihood of their complete realisation.

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